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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

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First Named Inventor	:	James E. Angelo et al.	Appeal No.
Appln. No.	:	09/469,597	
Filed	:	December 22, 1999	Group Art Unit: 2651
For	:	HEAD VIBRATION DETECTION DEVICE	Examiner: Varsha A. Kapadia
Docket No.	:	S01.12-0543	

REQUEST FOR REINSTATEMENT OF APPEAL AND SUPPLEMENTAL BRIEF FOR APPELLANT

Mail Stop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

I HEREBY CERTIFY THAT THIS PAPER IS BEING SENT BY U.S. MAIL, FIRST CLASS, TO THE COMMISSIONER FOR PATENTS, P.O. BOX 1450, ALEXANDRIA, VA 22313-1450, THIS

8 DAY OF November, 2004.

David D. Br

PATENT ATTORNEY

Sir:

This is an appeal from an Office Action dated September 9, 2004, which re-opened prosecution due to "new grounds of rejection". However, the Office Action presents no new grounds, but simply withdraws one of the previous rejections. Applicants request reinstatement of the Appeal.

REAL PARTY IN INTEREST

Seagate Technology LLC, a corporation organized under the laws of the state of Delaware, and having offices at 920 Disc Drive, Scotts Valley, CA 95066, has acquired the entire right, title and interest in and to the invention, the application, and any and all patents to be obtained therefor, as set forth in the Assignment filed with the patent application and recorded on Reel 010510, frame 0106.

RELATED APPEALS AND INTERFERENCES

There are no known related appeals or interferences, which will directly affect or be directly affected by or have a bearing on the Board's decision in this appeal.

STATUS OF THE CLAIMS

I.	Total number of claims in the application.		
		Claims in the application are:	1-26
II.	Status of all the claims.		
	A.	Claims cancelled:	none
	B.	Claims withdrawn but not cancelled:	none
	C.	Claims pending:	1-26
	D.	Claims allowed:	1-22
	E.	Claims rejected:	23-25
	G.	Claim allowable	26
III.	Claims on appeal		
		The claims on appeal are:	23-25

STATUS OF AMENDMENTS

The claims have been previously presented and there are no unentered amendments after Final.

SUMMARY OF INVENTION

One embodiment in which the present invention is useful is shown in FIG. 1. FIG. 1 illustrates a data storage device 50 including an actuator assembly 56, which rotationally supports heads 60 for reading data from and/or writing data to discs 54. (only one head shown in FIG. 1). (Page 3, lines 12-18). Heads 60 are coupled to the actuator 56 via head suspension assemblies 72. One embodiment of the present invention is directed to a head vibration detector on the head suspension assembly for detecting vibration of the supported head or its air bearing. (Page 4, lines 3-6).

In the embodiment illustrated in FIG. 3, head vibration is detected by a transducer 102, which is supported on a head suspension assembly 72, and a detector 104 (Page 4, lines 7-9). Transducer 102 can operate in a detection mode or an actuation mode. (Page 6, lines 5-6). Transducer 102 can include a piezoelectric or electrostatic transducer, for example, for producing a transducer signal proportional to mechanical movement

of the head suspension assembly 72 induced by head vibration while in the detection mode. (Page 6, lines 1-4). Opposed terminals 106, 108 of transducer 102 are orientated so that vibration or movement of transducer 102 along a detection axis 110 induces the transducer signal. (Page 4, lines 9-13). Detector 104 receives the transducer signal and outputs a signal indicative of head vibration. (Page 4, lines 16-18). This signal can be monitored by a process controller 136, shown in FIG. 6, to assure that data is not lost or corrupted due to vibration. (Page 5, line 28 to page 6, line 1).

FIG. 7 illustrates an embodiment of process control circuitry for operating transducer 102 in the detection mode and the actuator mode. (Page 6, lines 10-12). For read/write operations, drive circuitry 130 provides a position signal to servo control processor 140 to operate voice coil motor 142 for head placement through actuator 56 (shown in FIG. 1). (Page 6, lines 12- 16). As shown by the dashed line, transducer 102 is coupled to the suspension assembly 72 of a respective head so that vibration of the head strains the transducer to produce a transducer signal. (Page 6, lines 16-19).

In the detection mode, detector 104 receives the transducer signal and outputs a level detected signal indicative of head vibration. (Page 6, lines 19-22). In the actuator mode, a microactuator controller 144 transmits a signal to transducer 102 to adjust dimensions of transducer providing for fine head placement capabilities. (Page 6, lines 22-25).

FIGS. 8-9 schematically illustrate an embodiment of a suspension based transducer 102, which is configured to laterally move the heads as illustrated by arrow 150 in the actuation mode and to detect head vibration in the detection mode. (Page 6, lines 26-30 and page 7, lines 24-27). As discussed above with reference to FIG. 3, opposed terminal plates (154 and 156 in FIG. 9) of transducer 102 are aligned so that mechanical movement of

transducer 102 induces a potential across terminals of transducer 102 for detecting vibration modes of the head and its air bearing in the detection mode. (Page 7, lines 16-23). In the actuator mode, when a transducer signal is supplied to opposed terminals 154, 156, the length between ends 160, 162 expands and contracts depending upon the direction of the signal to laterally shift the position of the second suspension portion 72-2 relative to the first suspension portion 72-1 to actuate the heads as illustrated by arrow 150. (FIGS. 8 and 9, page 6, lines 9-15).

FIG. 10 illustrates an alternate embodiment of a suspension based transducer configured to micro-actuate a head as illustrated by arrow 150 in an actuation mode and aligned to induce a transducer signal for detecting head vibration in the detection mode. (Page 7, line 24 to page 8, line 5).

FIG. 11 is a flow chart, which illustrates operation of the transducer 102 in an actuation mode and a detection mode. (Page 8, lines 6-17).

ISSUES

I. Whether claim 23 is novel in view of Evans.

II. Whether claim 25 is novel in view of Evans.

III. Whether claim 24 is non-obvious over Evans in view of Novotny.

GROUPING OF CLAIMS

The following groupings of claims are made solely in the interest of consolidating issues and expediting this Appeal. No grouping of claims is intended to be nor should be interpreted as being any form of admission or a statement as to the scope or obviousness of any limitation.

Group I.	Claims 23;
Group II	Claim 24; and
Group III.	Claim 25

ARGUMENT

I. CLAIM 23 IS NOVEL IN VIEW OF EVANS ET AL.

Claim 23 was rejected under §102(e) as being anticipated by Evans et al., U.S. Patent No. 5,862,015.

As discussed above, claim 23 includes:

> a movable suspension assembly;
> an actuator coupled to the movable suspension assembly; and
> a detector coupled to the actuator and configured to receive a signal from the actuator proportional to vibration of the movable suspension assembly.

A. **Evans et al.**

Evans et al. is directed to a head suspension having a resonance feedback transducer.

As shown in FIG. 1, head suspension assembly 8 includes a strain transducer circuit 10, which functions as a strain gauge. (Col. 3, lines 27-29 and 55-56). Because transducer circuit 10 is mounted to head suspension assembly 8, strain in head suspension assembly 8 causes strain in transducer circuit lead 32, varying the electrical resistance of the transducer circuit. (Col. 4, lines 57-61).

FIG. 3 shows a block diagram of a system of monitoring off-neutral motion, which is described in column 5, lines 1-54. The change in resistance is converted to a voltage by converter 17, and servo control system 19 uses this information to control actuator system 21. The actuator system can include a primary actuator and/or a secondary or micro-actuator (not shown), which is separate from strain gauge 10.

FIG. 8 shows a suspension assembly 208 having strain gauges 10 and 234.

FIG. 10 shows a suspension assembly 308 having a microactuator 338 and a separate strain gauge 310. (See, col. 8, lines 34-47).

B. **Evans et al. do not Disclose the Elements of Claim 23.**

Evans et al. do not disclose "a detector coupled to the actuator and configured to receive a signal from the actuator proportional to vibration of the movable suspension assembly," as recited in claim 23.

The Office Action incorrectly suggests strain gauges 10, 234 and 310 in FIGS. 1, 3, 8 and 10 are "actuators" and that contacts 30 in FIGS. 1 and 3 and contacts 330 in FIG. 10 are detectors coupled to the so-called "actuators" and configured to receive a signal from the actuators proportional to vibration of the suspension assembly.

Evans et al. do not teach that elements 10, 234 and 310 are actuators. They are simple strain gauges that sense strain. The actuators in Evans et al. are clearly separate elements that have been ignored in the Office Action. However these actuators (such as actuator system 21 in FIG. 3 or microactuator 338 in FIG. 10) do not provide a signal that is proportional to vibration of a movable suspension assembly.

Also since strain gauges 10, 234 and 310 are not actuators, contacts 30 and 330 do not receive a signal from an actuator.

Since Evans et al. do not teach each and every element of claim 23, Applicants respectfully request that the rejection of claim 23 under §102(e) be reversed.

II. CLAIM 25 IS NOVEL IN VIEW OF EVANS ET AL.

Claim 25 was rejected under §102(e) as being anticipated by Evans et al., U.S. Patent No. 5,862,015.

Claim 25 further includes "a controller coupled to the

actuator and configured to transmit a signal to the actuator to move the movable suspension assembly."

The Final Action suggests, "Evans et al. further discloses a controller coupled to the actuator and configured to transmit a signal to the actuator to move the movable suspension assembly (see fig. 10 and col. 8, lines 10-46)." However the Office Action suggested above that the strain gauges 10, 234 and 310 were the "actuators".

Nowhere do Evans et al. disclose that a controller transmits a signal to the strain gauges 10, 234 and 310 to move the movable suspension assembly. That is because the strain gauges are not actuators. Rather, a controller controls the actuators 21 (FIG. 3) and 338 (FIG. 10). But these actuators do not provide "a signal proportional to vibration of the movable suspension assembly," as required by claim 23.

Thus, Evans et al. does not teach a controller coupled to an actuator as defined in claim 25.

Since Evans et al. do not teach each and every element of claim 25, Applicants respectfully request that the rejection of claim 25 under §102(e) be reversed.

III. CLAIM 24 IS NON-OBVIOUS OVER EVANS ET AL. IN VIEW OF NOVOTNY

Claim 24 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Evans in view of Novotny U.S. Patent No. 6, 362,542 on the basis that Novotny discloses a piezoelectric or electrostatic microactuator for precision head placement. (Col. 1, lines 34-37).

Claim 24 recites that the actuator is a piezoelectric or electrostatic actuator. However, claim 24 depends from claim 23. Thus, claim 24 requires such a piezoelectric or electrostatic actuator to provide a detector with "a signal from the actuator proportional to vibration of the movable suspension assembly."

Novotny does not teach or suggest a piezoelectric or electrostatic actuator that provides a detector with a signal that is proportional to vibration of a movable suspension assembly. Therefore, even if Evans et al. and Novotny were combined as the Examiner suggests, the resulting combination would still fail to teach or suggest the invention recited in claim 24.

Applicants respectfully request that the rejection of claim 24 under §103(a) be reversed.

The Director is authorized to charge any additional fees associated with this paper or credit any overpayment to Deposit Account No. 23-1123.

Respectfully submitted,

WESTMAN, CHAMPLIN & KELLY, P.A.

By: ____________________

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Appendix A

CLAIMS

1. (Allowed) A disc drive comprising:

   a disc rotationally coupled to a chassis;

   a movable head suspension assembly having a head coupled thereto movable relative to a surface of the disc;

   a transducer supported on the movable head suspension assembly and configured to induce a transducer signal proportional to movement of the head;

   a vibration detector configured to detect a transducer signal amplitude above a threshold amplitude and output a level detected signal indicative of head vibration.

2. (Allowed) The disc drive of claim 1 wherein the level detected signal is indicative of head-disc contact.

3. (Allowed) The disc drive of claim 1 wherein the vibration detector includes a frequency filter.

4. (Allowed) The disc drive of claim 3 wherein the frequency filter is configured to detect at least one of a bending mode or torsion mode.

5. (Allowed) The disc drive of claim 1 wherein the transducer is a piezoelectric material.

6. (Allowed) The disc drive of claim 1 wherein the transducer is an electrostatic transducer.

7. (Allowed) The disc drive of claim 1 and further comprising:

a process controller coupled to the detector and configured to receive the outputted level detected signal and output a process command to reexecute a write command in drive memory.

8. (Allowed) The disc drive of claim 1 and further comprising:

a controller coupled to the transducer on the movable head suspension assembly and configured to transmit a signal to the transducer to move the head.

9. (Allowed) The disc drive of claim 1 wherein the disc drive includes a plurality of discs rotationally coupled to the chassis and a plurality of movable head suspension assemblies having heads coupled thereto to read or write to surfaces of the plurality of discs and including a transducer coupled to each of the plurality of movable head suspension assemblies.

10. (Allowed) The disc drive of claim 19 wherein the transducer is configured to operate between a detection mode and an actuation mode, in the detection mode, the transducer detecting the vibration associated with the head suspension assembly and in the actuation mode the transducer receiving a signal to energize the transducer to move a head of the head suspension assembly.

11. (Allowed) The disc drive of claim 10 including:

a microactuator controller coupled to the transducer and configured to operate the transducer in the actuation mode.

12. (Allowed) A method for operating a disc drive comprising steps of:

(a) providing a transducer supported on a movable head suspension assembly having a head coupled thereto configured to generate a transducer signal indicative of head vibration; and

(b) detecting a signal amplitude of the transducer signal above a threshold amplitude and outputting a level detected signal indicative of the head vibration.

13. (Allowed) The method of claim 12 wherein the transducer is a piezoelectric transducer.

14. (Allowed) The method of claim 12 and further comprising the step of:

(c) transmitting a signal to the transducer on the movable suspension assembly to move the head.

15. (Allowed) The method of claim 12 and further comprising the step of:

(c) transmitting a command to rewrite a write command in drive memory in response to the level detected signal indicative of the head vibration.

16. (Allowed) The method of claim 12 and comprising the step of

(c) filtering the transducer signal to detect vibration frequencies of the head.

17. (Allowed) The method of claim 12 wherein the disc drive includes a plurality of head suspension assemblies and further comprising:

(c) individually detecting the head vibration for each of the plurality of head suspension assemblies.

18. (Allowed) The method of claim 12 including a microactuator controller coupled to the transducer and configured to transmit a signal to the transducer to move the head and comprising the step of:

(c) selectively operating the disc drive in a detection mode and an actuation mode, in the detection mode the transducer detecting the head vibration and in the actuation mode, the transducer moving the head.

19. (Allowed) A drive assembly comprising:

a movable head suspension assembly; and

a detector coupled to a transducer on the movable head suspension assembly that provides a signal indicative of a vibration associated with the head suspension assembly and the detector outputs a level detected signal that is responsive to the vibration being greater than a threshold value.

20. (Allowed) The method of claim 12 and comprising the step of:

(c) filtering the transducer signal to detect one of bending or torsion mode vibration frequencies.

21. (Allowed) The assembly of claim 19 in which the vibration is caused by head vibration.

22. (Allowed) The assembly of claim 19 wherein the detector includes a filter configured to pass a signal responsive to vibration frequencies associated with the head suspension assembly.

23. (On Appeal) An assembly comprising:

a movable suspension assembly;

an actuator coupled to the movable suspension assembly; and

a detector coupled to the actuator and configured to receive a signal from the actuator proportional to vibration of the movable suspension assembly.

24. (On Appeal) The assembly of claim 23 wherein the actuator is one of a piezoelectric or electrostatic actuator.

25. (On Appeal) The assembly of claim 23 and further comprising:

a controller coupled to the actuator and configured to transmit a signal to the actuator to move the movable suspension assembly.

26. (Allowable) The assembly of claim 23 including a controller configured to operate the actuator between an actuation mode to position a head of the movable suspension assembly and a detection mode to detect vibration of the head of the movable suspension assembly.

Appendix B

Exhibit A:	FIGS. 1-11
Exhibit B:	Evans et al., U.S. Patent No. 5,862,015.
Exhibit C:	Novotny U.S. Patent No. 6, 362,542.

FIG. 1

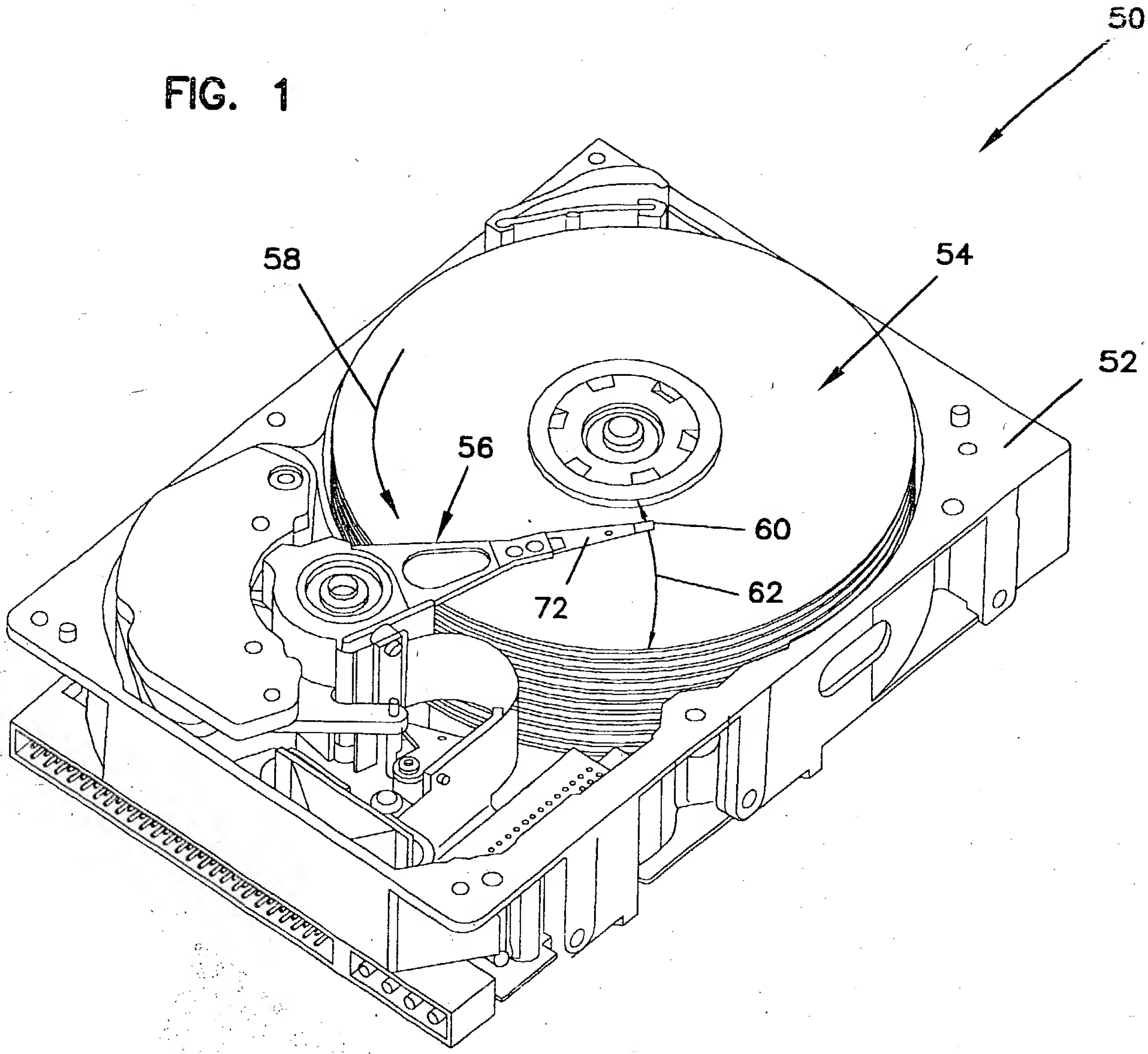
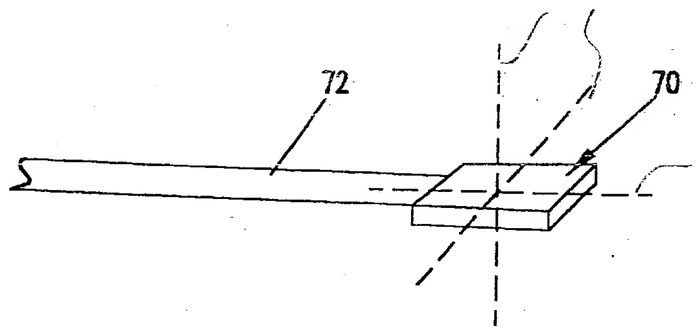
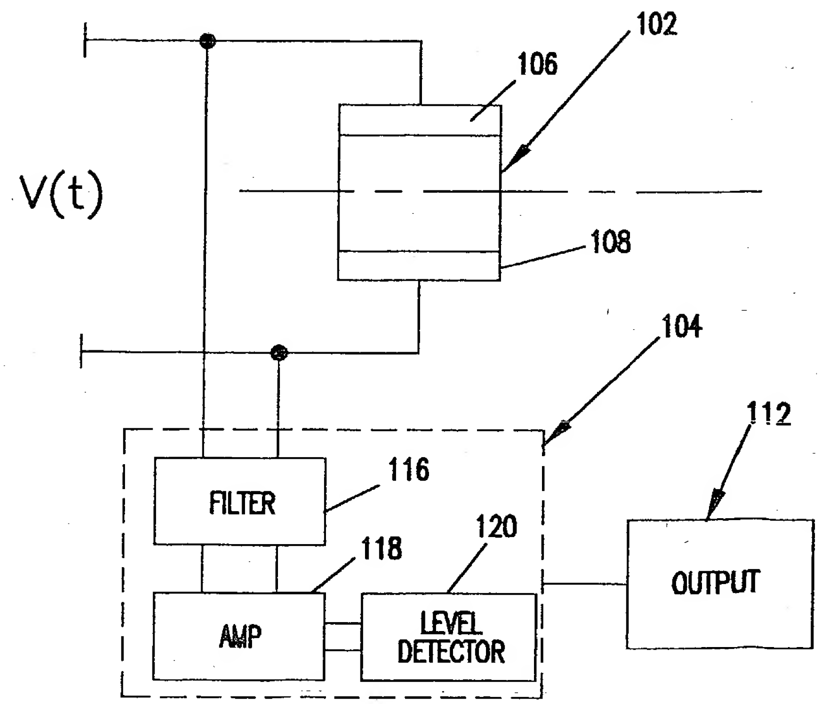


FIG. 2



72
70

FIG. 3



102
106
V(t)
108
104
112
FILTER
116
118
120
OUTPUT
AMP
LEVEL DETECTOR

FIG. 4

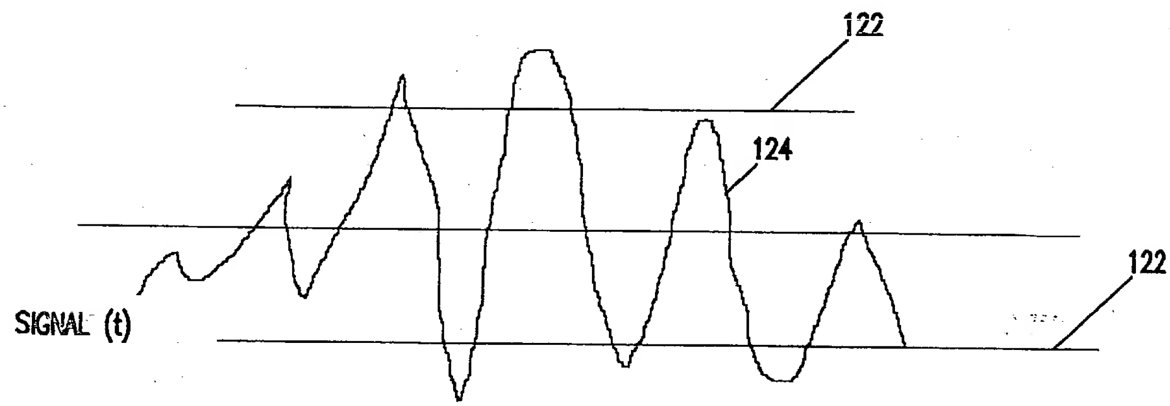

122
124
122
SIGNAL (t)

FIG. 6

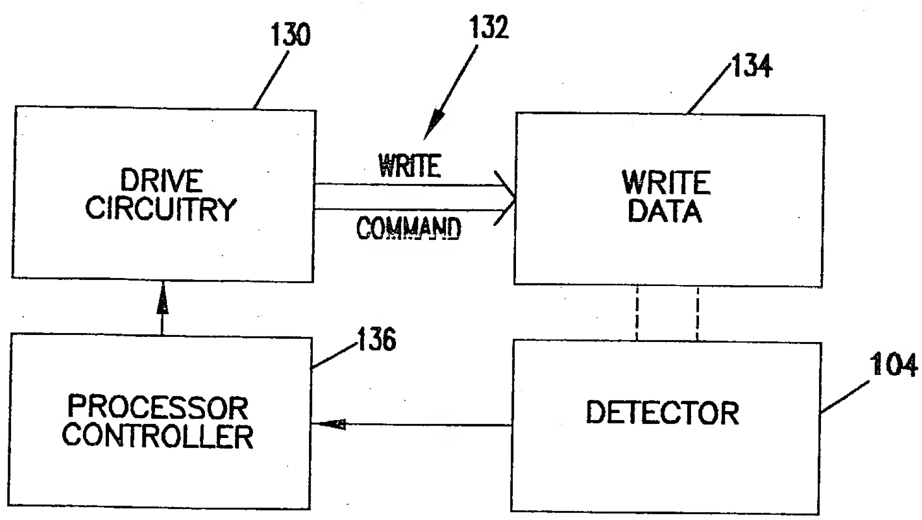

130
132
134
DRIVE CIRCUITRY
WRITE
COMMAND
WRITE DATA
136
104
PROCESSOR CONTROLLER
DETECTOR

FIG. 5

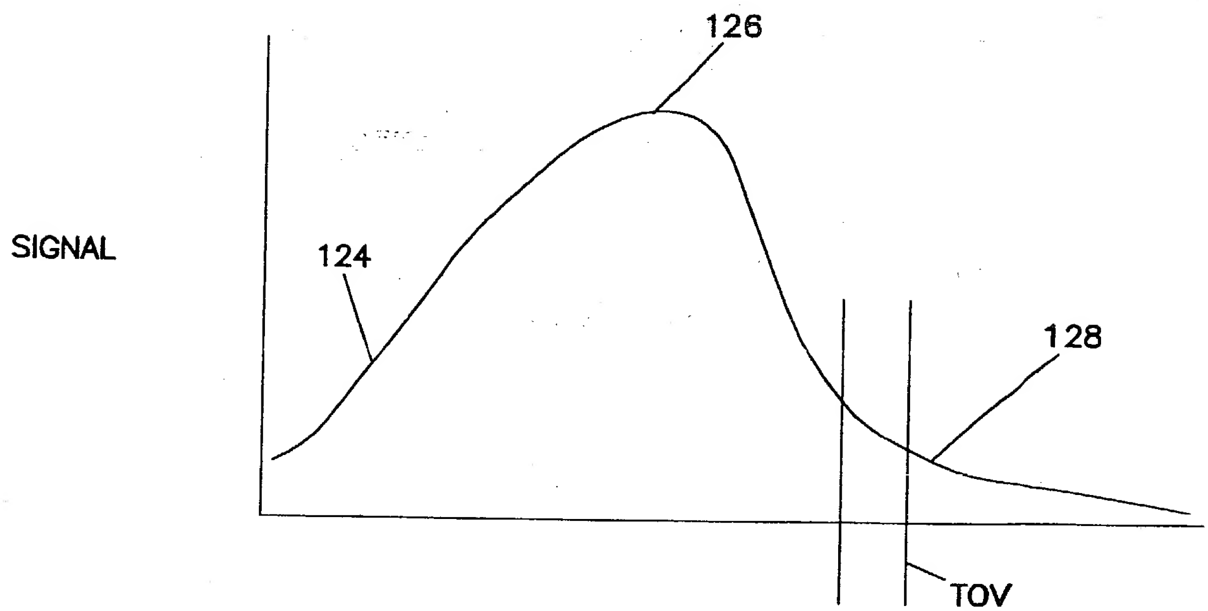


FIG. 7

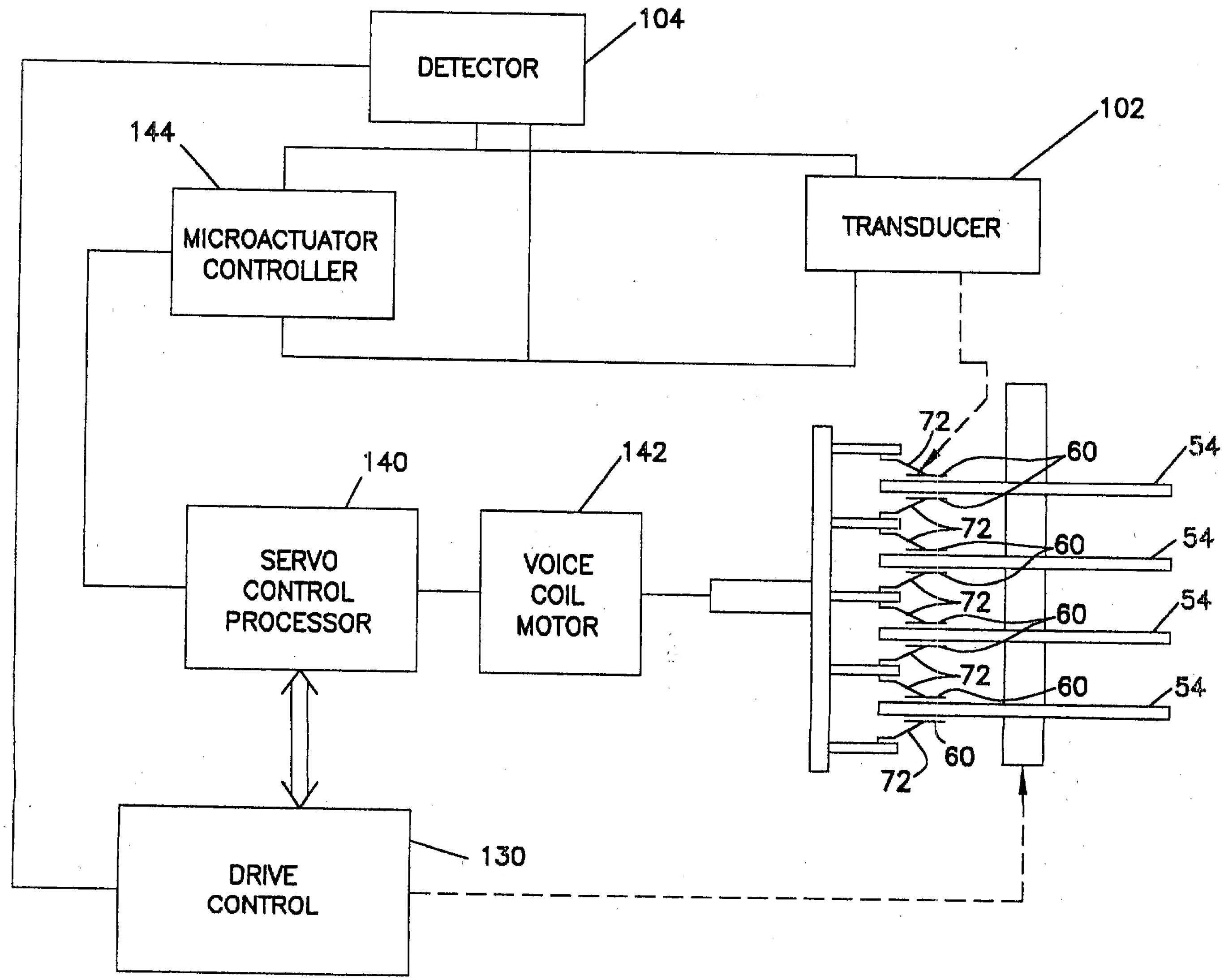
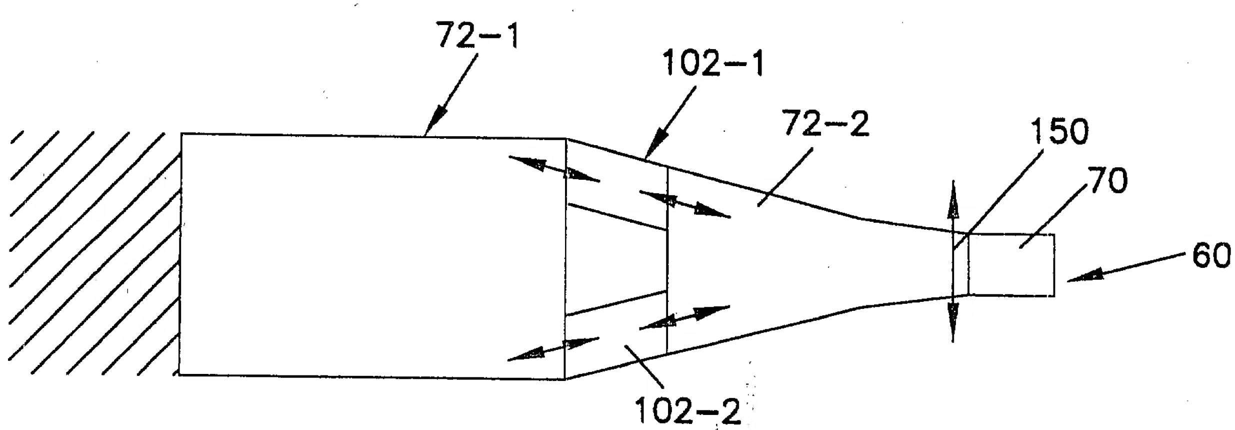
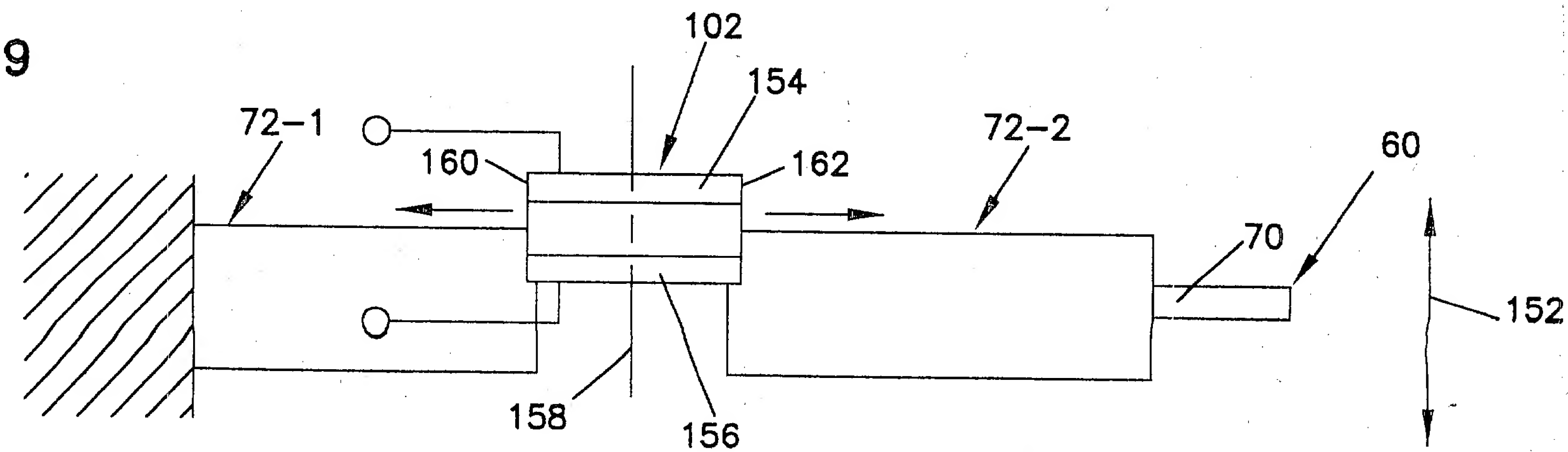

DETECTOR
104
102
144
MICROACTUATOR CONTROLLER
TRANSDUCER
72
60
54
140
142
SERVO CONTROL PROCESSOR
VOICE COIL MOTOR
72
60
54
72
60
54
72
60
54
60
72
DRIVE CONTROL
130

FIG. 8



72–1
102–1
72–2
150
70
60
102–2

FIG. 9



102
154
72–1
160
162
72–2
60
70
152
158
156

FIG. 10

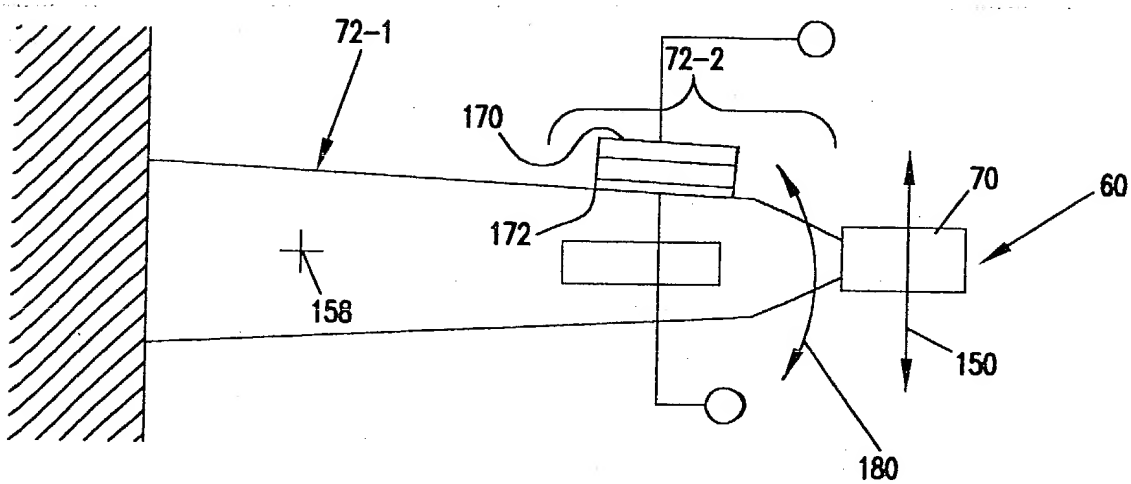
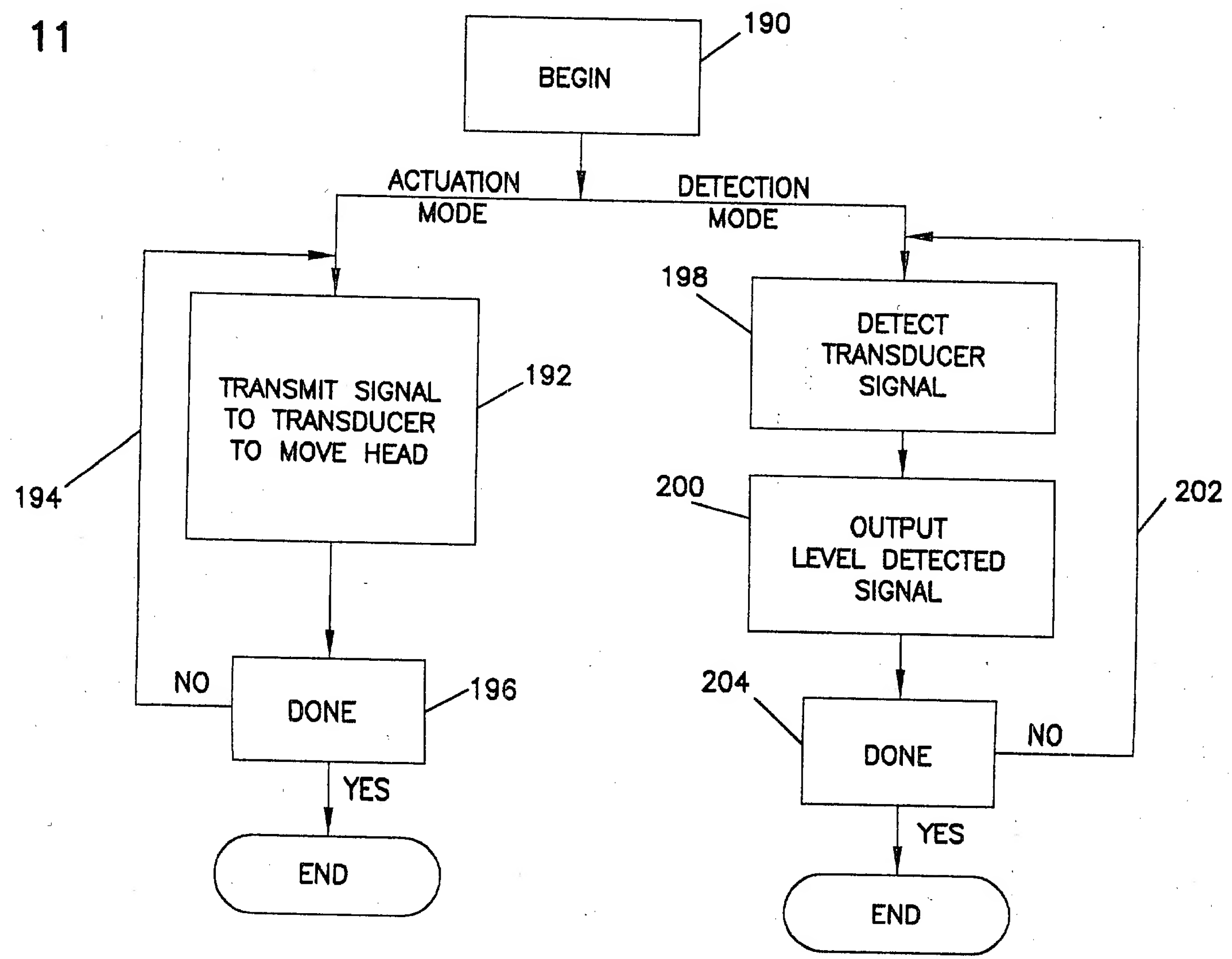


FIG. 11


BEGIN
190
ACTUATION MODE
DETECTION MODE
TRANSMIT SIGNAL TO TRANSDUCER TO MOVE HEAD
192
194
DONE
196
NO
YES
END
DETECT TRANSDUCER SIGNAL
198
OUTPUT LEVEL DETECTED SIGNAL
200
DONE
204
NO
202
YES
END

US005862015A

United States Patent [19]

Evans et al.

[11] **Patent Number: 5,862,015**

[45] **Date of Patent: Jan. 19, 1999**

[54] **HEAD SUSPENSION WITH RESONANCE FEEDBACK TRANSDUCER**

[75] Inventors: **Robert B. Evans**, Hutchinson; **Todd A. Krinke**, Long Lake, both of Minn.

[73] Assignee: **Hutchinson Technology Incorporated**, Hutchinson, Minn.

[21] Appl. No.: **861,530**

[22] Filed: **May 22, 1997**

Related U.S. Application Data

[60] Provisional application No. 60/018,167 May 23, 1996.

[51] **Int. Cl.**^{6} **G11B 5/48**

[52] **U.S. Cl.** **360/104**

[58] **Field of Search** 360/104

[56] **References Cited**

U.S. PATENT DOCUMENTS

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5,657,188	8/1997	Jurgenson et al.	360/106

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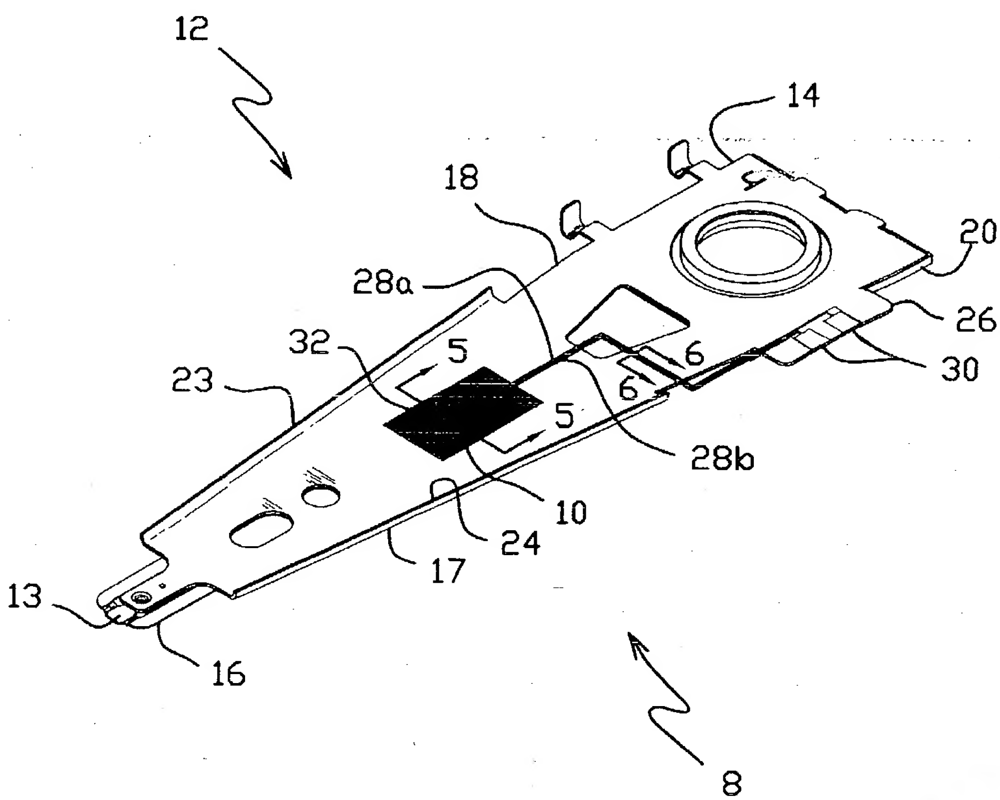
Lee et al., "Piezoelectric model sensor/actuator pairs for critical active damping vibrational control", J. Acoust. Soc. Am., vol. 90, No. 1, Jul. 1991, pp. 374–384.

Primary Examiner—John H. Wolff
Attorney, Agent, or Firm—Faegre & Benson LLP

[57] **ABSTRACT**

A head suspension assembly including a load beam having a rigid region, a mounting region on a proximal end of the load beam, and a flexure on a distal end of the load beam. The flexure has a read/write head attachment region for supporting a read/write head on the distal end of the load beam. Deformation of the head suspension assembly displaces the head attachment region. A strain transducer circuit that acts as a strain gauge is mounted on the head suspension assembly. The resistance of the transducer circuit varies with strain in the circuit, which, in turn, varies with displacement of the read/write head. The magnitude of resistance change of the transducer circuit indicates the magnitude of head off-neutral motion.

21 Claims, 8 Drawing Sheets



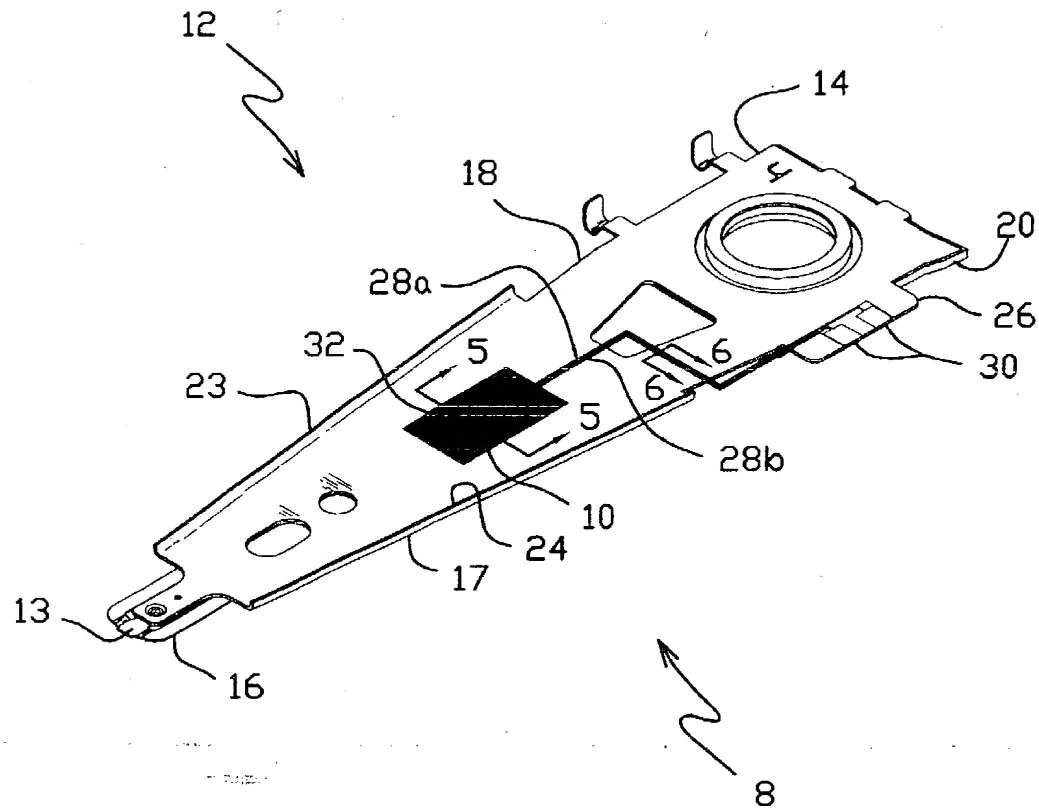


FIGURE 1

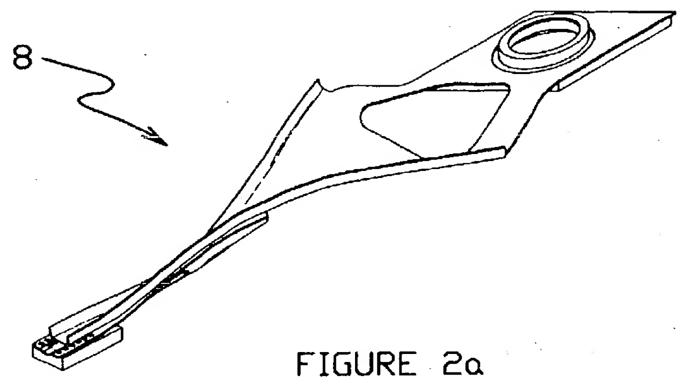


FIGURE 2a

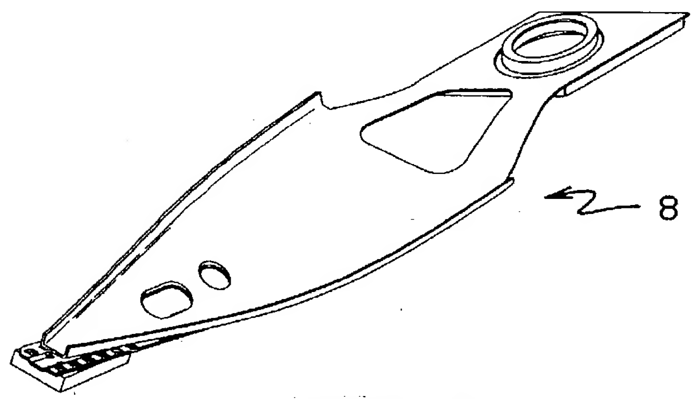


FIGURE 2b

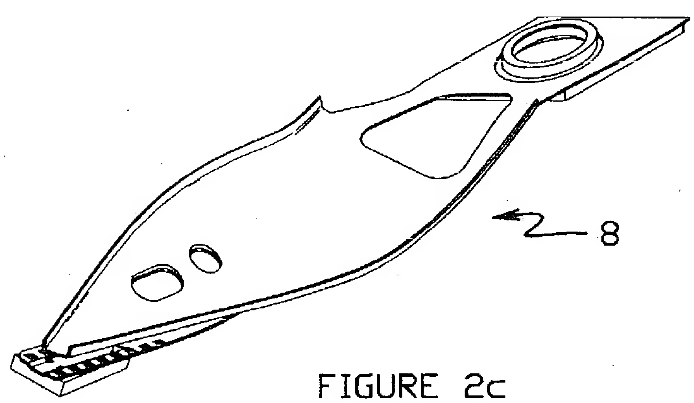


FIGURE 2c

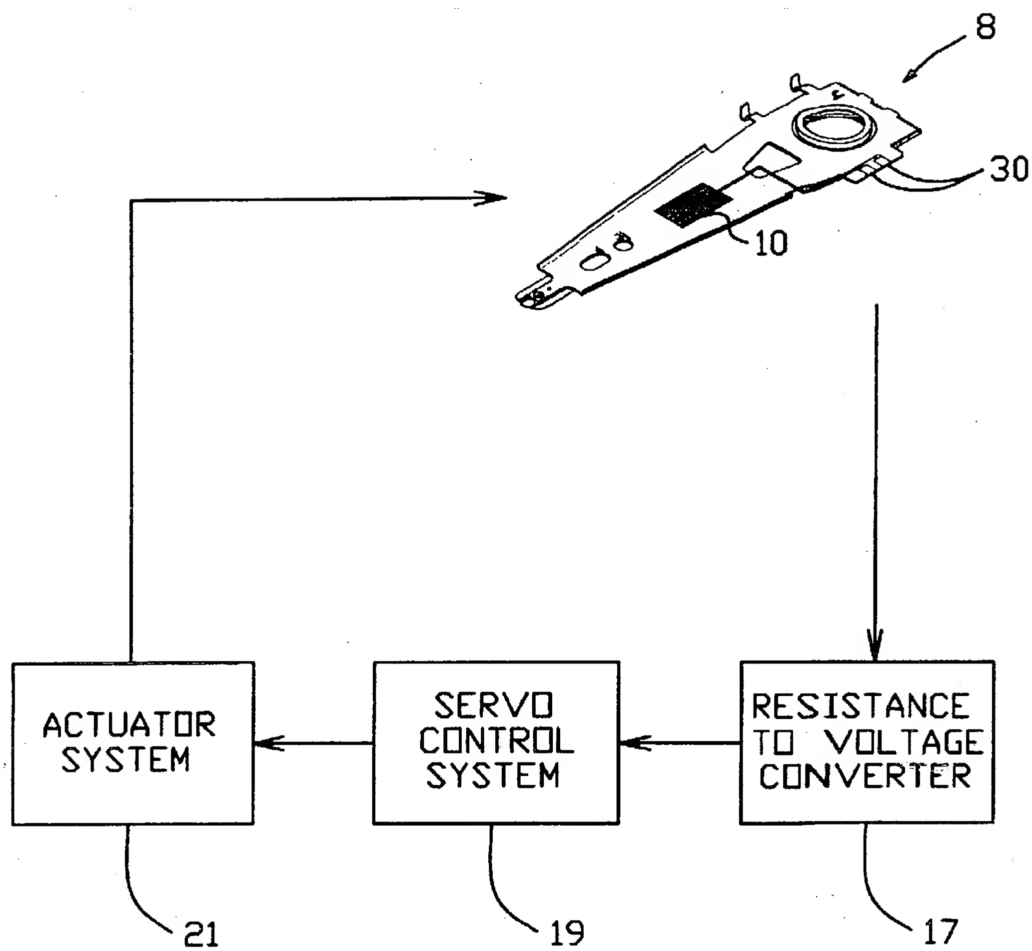

8
30
10
ACTUATOR SYSTEM
SERVO CONTROL SYSTEM
RESISTANCE TO VOLTAGE CONVERTER
21
19
17

FIGURE 3

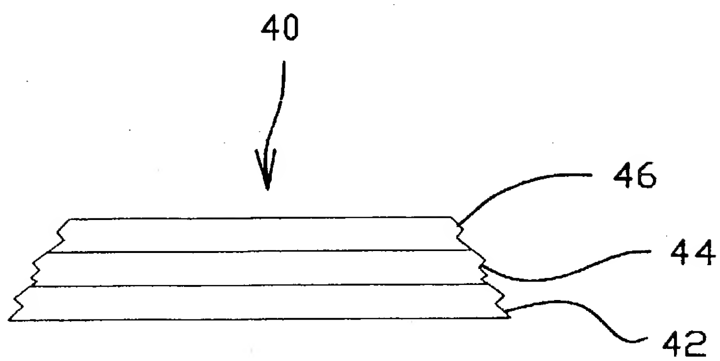


FIGURE 4

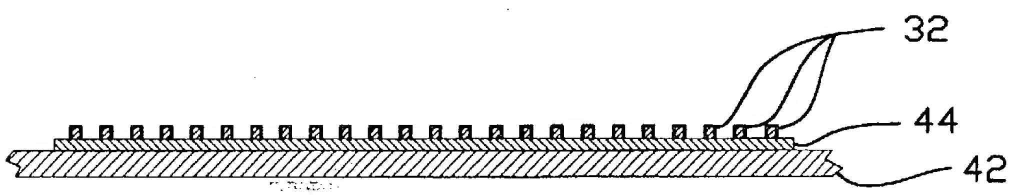


FIGURE 5

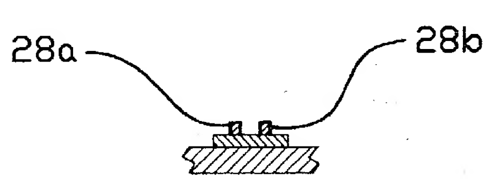


FIGURE 6

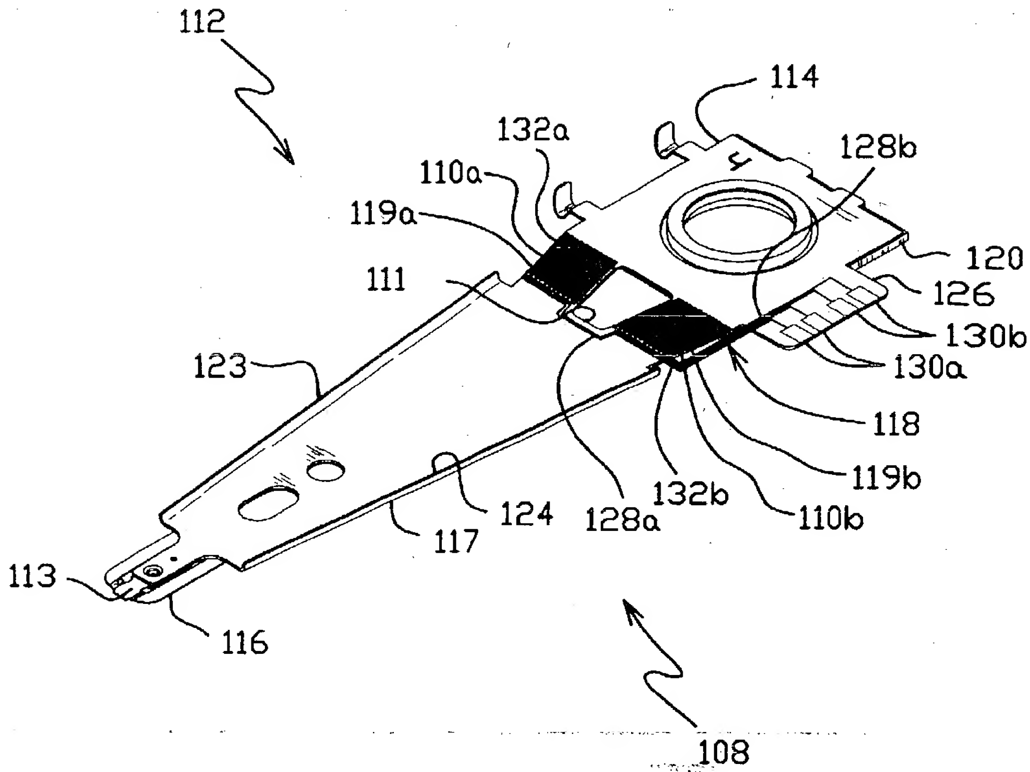

112
114
132a
128b
110a
119a
120
111
126
130b
123
130a
118
119b
132b
124
128a
110b
117
113
116
108

FIGURE 7

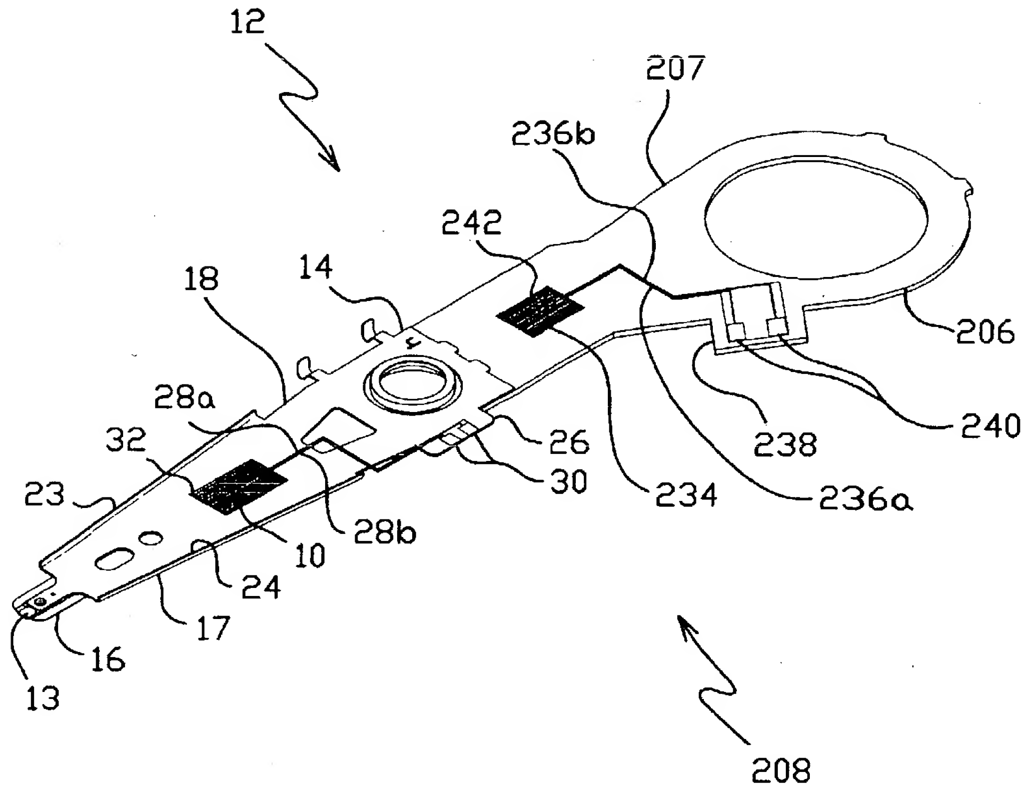

12
207
236b
242
18
14
206
28a
32
26
30
238
240
23
234
236a
28b
10
24
17
16
13
208

FIGURE 8

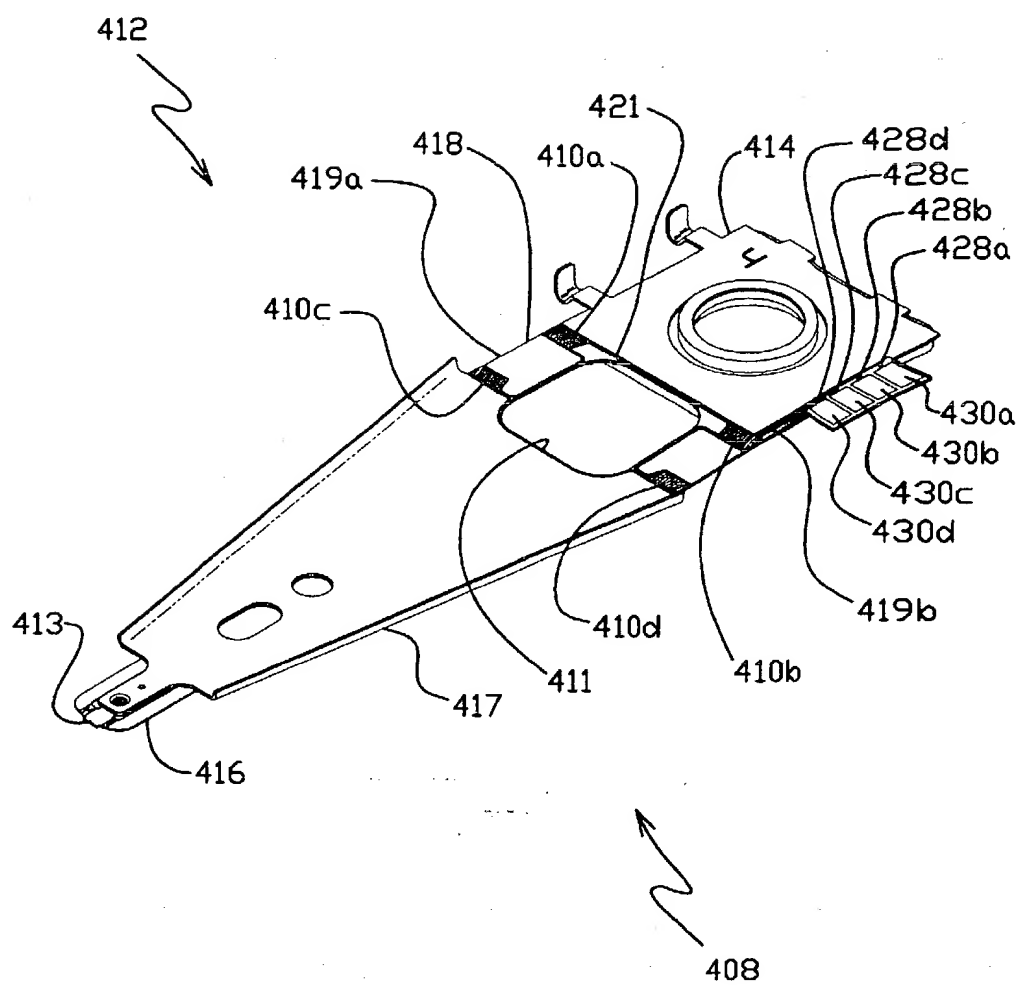

412
421
418
410a
414
428d
428c
428b
428a
419a
410c
430a
430b
430c
430d
419b
410d
410b
413
417
411
416
408

FIGURE 9

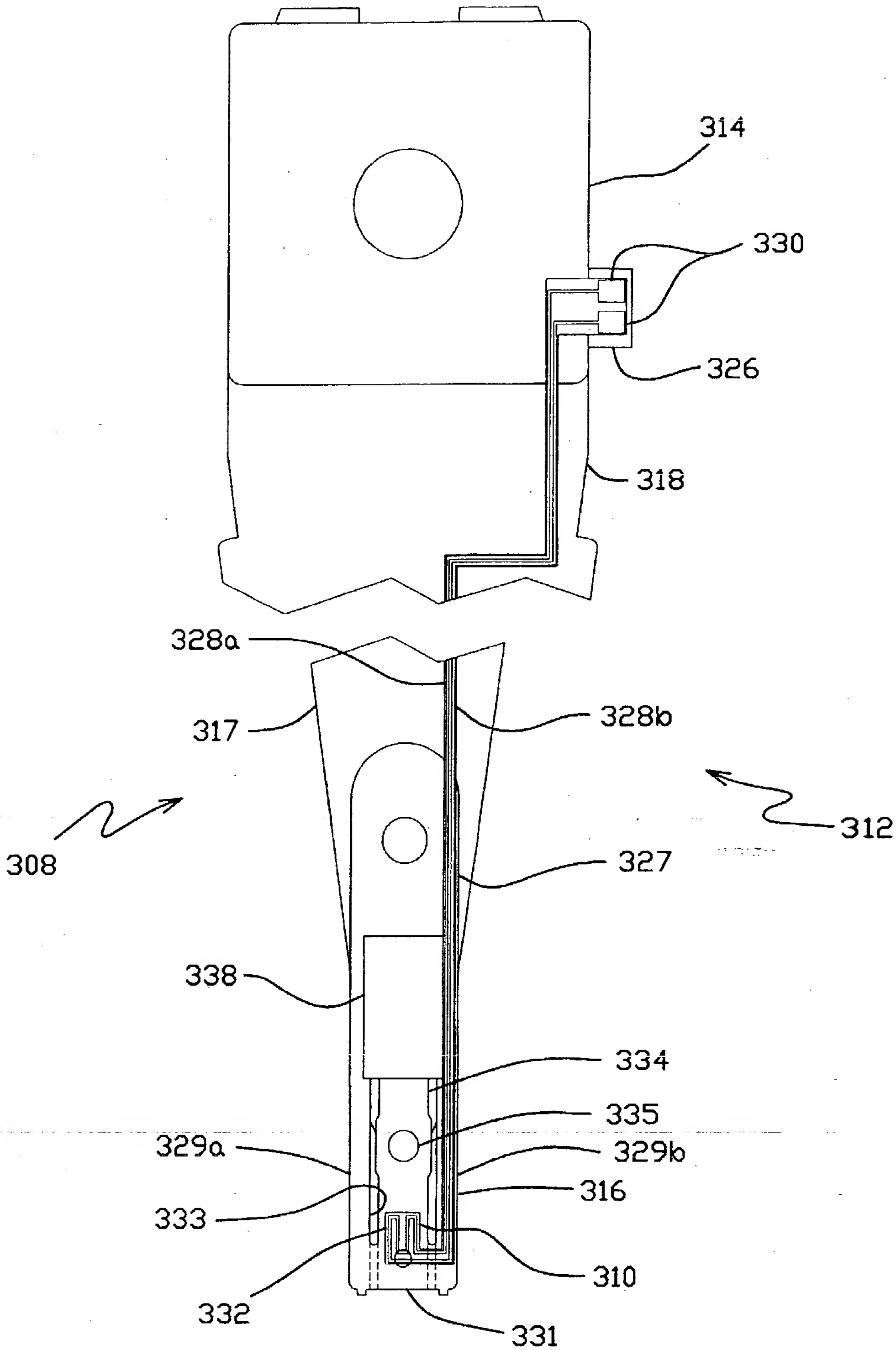

314
330
326
318
328a
328b
317
312
308
327
338
334
335
329a
329b
316
333
310
332
331

FIGURE 10

HEAD SUSPENSION WITH RESONANCE FEEDBACK TRANSDUCER

REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional application Ser. No. 60/018,167, filed May 23, 1996 abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to suspensions for supporting read/write heads over recording media. In particular, the present invention relates to a head suspension assembly with a strain transducer circuit thereon for detecting motion of the head suspension assembly out of a neutral position.

2. Description of the Related Art

Information storage devices typically include a read/write head for reading and/or writing data onto a storage medium such as a magnetic disk within a rigid disk drive. An actuator mechanism driven by a servo control is used to position the head at specific radial locations or tracks on the magnetic disk. Both linear and rotary type actuators are well known in the art. Between the actuator and the head, a head suspension is required to support the head in proper orientation relative to the disk surface.

The head suspension carries the read/write head so that the head can "fly" over the surface of the rigid disk while the disk is spinning. The head is typically located on a head slider having an aerodynamic design so that the head slider flies on an air bearing generated by the spinning disk. The combination of the head slider and the head suspension is referred to as a head suspension assembly. The head suspension includes a load beam which has a radius or spring section, a rigid region, and a flexure. The flexure is a spring or gimballing connection typically included between the head slider and the rigid section of the load beam so that the head slider can move in the pitch and roll directions of the head to accommodate fluctuations of the disk surface. The mounting region of the load beam is typically attached to an actuator arm which supports the suspension assembly over the rotating disk. A base of the actuator arm is coupled to an actuator.

When no external forces (with the exception of gravity) are acting on the head suspension assembly to deform it in any way, it is in a "neutral un-loaded" state. When the head is flying over the spinning surface of a disk, and is acted upon only by the force of the air bearing generated by the spinning disk, the head suspension assembly is in a "neutral loaded" state. However, the head suspension assembly can experience deformations that cause motion of the head away from either the neutral loaded or neutral un-loaded positions.

One way these deformations can occur involves a head suspension's tendency to bend and twist in a number of different modes, known as resonant frequencies, when driven back and forth at certain rates. Any such bending or twisting of a suspension can cause the position of the head to deviate from its neutral loaded or neutral un-loaded position.

Common bending and twisting modes of suspensions are generally known and discussed, for example, in the Yumura et al. U.S. Pat. No. 5,339,208 and the Hatch et al. U.S. Pat. No. 5,471,734. Modes which result in lateral or transverse motion (also known as off-track motion) of the head slider are particularly detrimental since this motion causes the

head slider to move from the desired track on the disk toward an adjacent track. The three primary modes which produce this transverse motion are known as the sway, first torsion, and second torsion modes. The sway mode is a lateral bending mode in which the suspension bends in a transverse direction along its entire length. The first and second torsion modes are twisting modes during which the suspension twists about a rotational axis which extends along the length of the suspension.

Deformations of the suspension can also be caused by a secondary-actuation or microactuation device designed to move the head relative to the remainder of the head suspension assembly. Such a microactuation device is disclosed in U.S. patent application Ser. No. 08/457,432 filed Jun. 6, 1995 by Jurgenson et al. for a Head Suspension with Tracking Microactuator now U.S. Pat. No. 5,657,188.

Whether generated by motion during resonant modes, a secondary actuation device, or other causes, it can be useful to monitor motion of the head away from a neutral loaded or neutral un-loaded position, that is, read/write head off-neutral motion. Information about head off-neutral motion caused by undesirable resonant vibrations can be used to actively damp such vibrations. Further, monitoring of the displacement of the head caused by a first actuator can be important to correct placement of the head by a second actuator.

SUMMARY OF THE INVENTION

The present invention provides a means for detecting the off-neutral motion of a head mounted on a head suspension assembly. This information can be used to correct head off-neutral motion, if necessary, so that read/write operations can be accomplished relatively quickly and accurately. It can also be used to determine the displacement of a magnetic head caused by a microactuation device to allow accurate placement of the head by a primary actuator. The head suspension assembly includes a load beam having a proximal end, a distal end, a mounting region on the proximal end, and a rigid region adjacent to the distal end. A flexure is at the distal end of the load beam. A strain transducer circuit is located on the head suspension assembly and detects strain in the head suspension assembly. In one embodiment, the flexure includes a head attachment region where the read/write head is attached. Deformation of the head suspension assembly displaces the head attachment region from a neutral position and subjects the head suspension assembly to strain. The strain transducer circuit detects the strain which allows detection of motion of the head attachment region out of the neutral position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of a head suspension assembly including a strain transducer circuit on a load beam in accordance with the present invention.

FIG. 2*a* is an isometric view of the suspension assembly shown in FIG. 1 undergoing twisting motion in the first torsion mode.

FIG. 2*b* is an isometric view of the suspension assembly shown in FIG. 1 undergoing twisting motion in the second torsion mode.

FIG. 2*c* is an isometric view of the suspension assembly shown in FIG. 1 undergoing bending motion in the sway mode.

FIG. 3 is a block diagram showing a system for detecting motion of a head suspension assembly out of neutral position in accordance with the present invention.

FIG. **4** is a side view of laminated sheet material from which the head suspension shown in FIG. **1** can be fabricated.

FIG. **5** is a sectional view of the head suspension assembly shown in FIG. **1** taken along line **5**—**5**.

FIG. **6** is a sectional view of the head suspension assembly shown in FIG. **1** taken along line **6**—**6**.

FIG. **7** is an isometric view of a head suspension assembly including first and second strain transducer circuits in accordance with a second embodiment of the present invention.

FIG. **8** is an isometric view of a head suspension assembly including an actuator arm and first and second strain transducer circuits in accordance with a third embodiment of the present invention.

FIG. **9** is an isometric view of a head suspension assembly including an actuator arm and first, second, third, and fourth strain transducer circuits in accordance with a fourth embodiment of the present invention.

FIG. **10** is a top view of a head suspension assembly including a microactuation device and strain transducer circuit in accordance with a fifth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A head suspension assembly **8** which includes a strain transducer circuit **10** in accordance with the present invention is illustrated generally in FIG. **1**. As shown, head suspension assembly **8** includes a load beam **12** having a base or mounting region **14** on a proximal end, a flexure **16** on a distal end, a relatively rigid region **17** adjacent to the flexure, and a radius or spring region **18** between the base **14** and rigid region **17**. The flexure **16** supports a head slider (not shown) which is mounted on a head attachment region **13** and which "flies" on an air bearing created by a spinning magnetic disk (not shown). The head slider supports a read/write head (not shown) for transferring data to, and reading data from the spinning magnetic disk. A base plate **20** is welded to base **14** for mounting the load beam **12** to a disk drive actuator arm (not shown). Flexure **16** is a spring connection provided between a head slider and the distal end of the load beam **12** which permits the head slider to move in pitch and roll directions so that it can compensate for fluctuations of the spinning disk surface above which the slider flies. Many different types of flexures, also known as gimbals, are known to provide the spring connection allowing for pitch and roll movement of the head slider and can be used with the present invention. First and second edge rails **23** and **24** are formed in transversely opposite sides of the rigid region **17** of load beam **12**. Tab **26** which extends from base **14** is used to position and support read/write head lead wires (not shown), transducer circuit lead wires ***28a*** and ***28b***, and electrical contacts **30**.

The strain transducer circuit **10** is located in the transverse center of load beam **12** and functions as a strain gauge. Strain gauges are well known in the art and any suitable strain gauge is contemplated to be used with the present invention. In the embodiment of FIG. **1**, individual transducer circuit lead **32** of transducer circuit **10** is formed from a single electrical lead which extends longitudinally back and forth in parallel sections connected at ends of the sections. Other orientations and configurations of circuit lead **32** are also within the ambit of the present invention. For example the electrical lead can be configured in a circular spiral or other non-parallel configurations. FIG. **5** is a sectional view of load beam **12** taken along line **5**—**5** and showing transducer circuit lead **32**. Lead wires ***28a*** and ***28b*** are connected to opposite ends of circuit lead **32** to form a continuous closed circuit between lead wires ***28a*** and ***28b***. FIG. **6** is a sectional view of load beam **12** taken along line **6**—**6** and showing lead wires ***28a*** and ***28b***. Lead wires ***28a*** and ***28b*** are connected to contacts **30** on tab **26**.

Transducer circuit lead **32** is fabricated of a material in which the electrical resistance varies with strain on the material. In the embodiment of FIG. **1**, circuit lead **32** is formed of Constantan, a commercially available nickel-copper alloy. Transducer circuit lead **32** can also be formed of any other material in which electrical resistance varies as the strain on the material varies.

When head suspension assembly **8** is acted upon by no external forces it is in a neutral un-loaded position. When the head suspension assembly **8** is acted on only by the force of the air bearing on which the slider flies, the head suspension assembly is in a neutral loaded (fly-height) position. Hereinafter, the term "neutral" will be used to refer to either the neutral un-loaded position or neutral loaded position. When the head suspension assembly **8** is in a neutral position, it holds the read/write head attachment region **13**, and thereby the read/write head (not shown), in a neutral position with respect to a base **14** of the load beam **12**. However, head suspension assembly **8** can elastically deform out of neutral position moving the head attachment region **13** out of neutral position. This causes read/write head off-neutral motion.

This kind of motion can occur as a result of motion in resonant modes causing oscillatory excursions of a head suspension assembly about its neutral position. As is discussed generally in the Description of the Related Art section of this document, when in operation, head suspension assemblies such as **8** bend and twist in a number of different modes, known as resonant frequencies, when driven back and forth at certain rates of speeds. FIG. ***2a*** is an illustration of suspension assembly **8** undergoing twisting motion in what is known as the first torsion mode. FIG. ***2b*** is an illustration of suspension assembly **8** undergoing twisting motion in what is known as the second torsion mode. In both the first and second torsion modes the load beam **12** of suspension assembly **8** twists or rotates about a central, longitudinally oriented rotational axis. FIG. ***2c*** is an illustration of suspension assembly **8** undergoing bending motion in what is known as the sway mode. In the sway mode the load beam **12** bends about an axis that is perpendicular to the base of the load beam. Typically, the sway mode exhibits a slight twisting motion as well.

Read/write head off-neutral motion can also be caused by a microactuation device on a head suspension assembly, such as microactuator **338** shown in FIG. **10**, intentionally designed to move a portion of the suspension assembly out of its neutral position.

Generally, the greater the motion of a head suspension assembly out of neutral position, the greater the strain thereon. Referring again to FIG. **1**, because transducer circuit **10** is mounted to head suspension **8**, strain in head suspension **8** causes strain in transducer circuit lead **32** of transducer circuit **10**, varying the electrical resistance of transducer circuit **10**. In this way, the electrical resistance of transducer circuit **10** varies with motion of the head attachment region **13** out of neutral position. This variation in resistance can be converted into an electrical signal using a wheatstone bridge or other methods known in the art, and used to monitor motion of the head attachment region out of neutral position, that is, read/write head off-neutral motion.

FIG. 3 shows a block diagram of a system to monitor read/write head off-neutral motion using the transducer circuit **10** in accordance with the present invention. A deformation of head suspension assembly **8** causes read/write head off-neutral motion. Deformation of head suspension assembly **8**, as explained above, also causes strain in transducer circuit lead **32** which changes the electrical resistance of transducer circuit **10**. The resistance of transducer circuit **10** can be detected across contacts **30** and can then be converted into a voltage by a resistance to voltage converter **17**, such as a wheatstone bridge or other well known means. The converter **17** can then be electrically connected to a servo control system **19**. In this way, the servo control system **19** can be provided with the head off-neutral motion information. If necessary, servo control system **19** can then act to correct or minimize head off-neutral motion through appropriate control of actuator system **21**, which can include a primary and/or a secondary or micro-actuator which actuate head suspension **8**. This would be desirable if, for example, head off-neutral motion was caused by resonance vibrations in head suspension assembly **8**. Correction of head off-neutral motion may not be desirable, however, if it is intentionally caused by a micro-actuation device as shown in the embodiment shown in FIG. **10**. In such a case, monitoring head off-neutral motion can still be important for correct placement of the load beam **12** by a primary actuator.

It should be noted that converter **17** can be incorporated onto the head suspension assembly itself by forming a wheatstone bridge on the suspension assembly from four strain transducer circuits as shown in FIG. 9.

The position at which transducer circuit **10** is located can be determined on the basis of the specific types of deformations that are desired to be monitored. As noted above, it is possible to use the transducer circuit **10** to detect whether the head suspension assembly **8** is undergoing motion in a resonant mode that could cause off-track error and increase read/write function time. Different resonant modes more severely strain different sections of the head suspension assembly. For monitoring off-neutral head motion in a resonant mode, it is desirable to locate the transducer circuit **10** at a location of relatively high strain for that particular resonant mode.

The location on a head suspension assembly that a particular mode strains most severely is dependent upon the design of the particular suspension assembly. Which section of a given suspension assembly is most strained for a given resonant mode (i.e. the location of the nodes for that mode) is generally known, can be determined empirically, or can be determined using methods of computer modeled finite element analysis known in the art. The transducer circuit can then be placed on the section of the suspension assembly that experiences relatively high strain during a condition of resonance in a chosen mode.

A method for manufacturing load beam **12** and transducer circuit **10** can be described with reference to FIGS. **4**, **5** and **6**. In the embodiment of FIG. 1, all the features of load beam **12** with the exception of the flexure **16** and baseplate **20** are manufactured from a single sheet of laminated material **40** shown in FIG. 4. FIG. 5 shows a sectional view of load beam **12** taken along line **5**—**5**. FIG. 6 shows a sectional view of load beam **12** taken along line **6**—**6**. Material **40** includes a lower layer **42** of stainless steel or other resilient material; an intermediate layer **44** of polyimide or other dielectric material overlaying the lower layer; and an upper layer **46** of Constantan or other material in which the resistance varies in relation to strain. Using etching or otherwise known techniques, blanks having the desired external dimensions of load beam **12** are formed from the sheet of material **40**. The lower layer **42** is patterned and etched to form base **14**, spring region **18**, rigid region **17**, and first and second edge rails **23** and **24**. Intermediate layer **44** and upper layer **46** are then patterned and etched to form transducer circuit lead **32**, lead wires **28***a* and **28***b*, and contacts **30**. First and second edge rails **23** and **24** are then formed in the edges of load beam **17**. In other embodiments (not shown), transducer circuit **10** can be separately fabricated and bonded by adhesive or other means to a conventional or otherwise manufactured load beam. Also, additive processes, such as plating, sputtering, or vapor deposition, or other processes known in the art may be used to form the transducer circuit **10** on suspension **8**.

FIG. **7** is an illustration of a suspension assembly including another embodiment of the present invention. Elements in FIG. **7** which are functionally similar to those of FIG. **1** are labeled with like numerals incremented by 100. As shown in FIG. **7**, a head suspension assembly **108** includes a load beam **112** having a base or mounting region **114** on a proximal end, a flexure **116** on a distal end, a relatively rigid region **117** adjacent to the flexure, and a radius or spring region **118** between the base **114** and rigid region **117**. Flexure **116** includes read/write head attachment region **113**. An open region **111** is formed in the transverse center of spring region **118** forming a pair of spring arms **119***a* and **119***b*. In the embodiment of FIG. 7, strain transducer circuits **110***a* and **110***b*, which act as strain gauges, are mounted on spring arms **119***a* and **119***b*, respectively. Individual transducer circuit lead **132***a* of transducer circuit **110***a* is a single connected lead that extends longitudinally back and forth in parallel sections connected at ends of the sections. Lead wires **128***a* connect transducer circuit **110***a* to contacts **130***a* and lead wires **128***b* connect transducer circuit **110***b* to contacts **130***b*. Tab **126** supports contacts **130***a* and **130***b*. Head suspension assembly **108** can be manufactured in a manner similar to that of head suspension assembly **8** shown in FIG. **1**.

In the embodiment shown in FIG. **7**, the transducer circuits **110***a* and **110***b* are placed in a position of relatively high strain for either the first and second torsion modes or the sway mode.

FIG. **8** is an illustration of a head suspension assembly **208** including another embodiment of the present invention. In FIG. **8**, the head suspension assembly **208** includes an actuator arm **207** to which the mounting region **14** of load beam **12** is attached. Actuator arm **207** is connected at base **206** to a servo actuator (not shown) and carries and positions load beam **12** above a spinning magnetic disk (not shown). A strain transducer circuit **234** which acts as a strain gauge is located on the actuator arm **207**. In the embodiment of FIG. **8**, individual transducer circuit lead **242** of transducer circuit **234** is a single connected lead which crosses longitudinally back and forth in parallel sections connected at the ends of the sections. As noted previously, other configurations of circuit lead **242** are also within the ambit of the present invention. Lead wires **236***a* and **236***b* connect to opposite ends of transducer circuit **234** to form a closed circuit between lead wires **236***a* and **236***b*. Tab **238** supports electrical contacts **240**.

In the embodiment shown in FIG. **8**, transducer circuit **10**, as discussed above, detects deformation in load beam **12**. Further, deformations of actuator arm **207** can cause motion of head attachment region **13** on flexure **16** out of a neutral position with respect to base **206** of actuator arm **207**. Transducer circuit 242 detects deformation of actuator arm

207 and thereby detects read/write head off-neutral motion with respect to base 206 caused by deformation in actuator arm 207. The signals from transducer circuits 10 and 242 can be fed to a servo controller (not shown) to facilitate correction or control of head off-neutral motion as necessary.

Actuator arm 207 can be manufactured from a sheet of laminated material 40 as shown in FIG. 4 having a lower layer 42 of stainless steel or other resilient material, an intermediate layer 44 of polyimide or other dielectric, and an upper layer 46 of Constantan or other material in which electrical resistance varies with strain. Using etching or otherwise known techniques, blanks having the desired external dimensions of actuator arm 207 are formed from the sheet of material 40. The lower layer 42 is patterned and etched to form base 206 and tab 238. Intermediate layer 44 and upper layer 46 are then patterned and etched to form transducer circuit lead 242, lead wires 236*a* and 236*b*, and contacts 240. In other embodiments (not shown), transducer circuit 234 can be separately fabricated and bonded by adhesive or other means to a conventional or otherwise manufactured actuator arm. Load beam 12 can be mounted to actuator arm 207 by welding or other known means. Also, additive processes, such as plating, sputtering, or vapor deposition, or other processes known in the art may be used to form the transducer circuit 234 on actuator arm 207.

FIG. 9 is an illustration of a suspension assembly showing another embodiment of the present invention. Elements if FIG. 9 which are functionally similar to those of FIG. 1 are shown with like numerals incremented by 400. As shown in FIG. 9, a head suspension assembly 408 includes a load beam 412 having a base or mounting region 414 on a proximal end, a flexure 416 on a distal end, a relatively rigid region 417 adjacent to the flexure, and a radius or spring region 418 between the base 414 and rigid region 417. Flexure 416 includes read/write head attachment region 413. An open region 411 is formed in the transverse center of spring region 418 forming a pair of spring arms 419*a* and 419*b*. In the embodiment of FIG. 9, first and second strain transducer circuits 410*a* and 410*c* are mounted on spring arm 419*a* and third and forth strain transducer circuits 410*b* and 410*d* are mounted on spring arm 419*b*. Transducer circuits 410*a*, 410*b*, 410*c* and 410*d* are electrically connected together by electrical lead 421 to form a wheatstone bridge circuit. This wheatstone bridge circuit is then connected by electrical leads 428*a*, 428*b*, 428*c*, and 428*d* to electrical contacts 430*a*, 430*b*, 430*c*, and 430*d*, respectively. In this way, read/write head off neutral motion of suspension assembly 408 can be detected directly as a voltage and the need for an external resistance to voltage converter is obviated. Head suspension assembly 408 can be manufactured in a manner similar to that of head suspension assembly 8 shown in FIG. 1.

FIG. 10 is an illustration of a suspension assembly showing yet another embodiment of the present invention. Elements in FIG. 10 which are functionally similar to those of FIG. 1 are shown with like numerals incremented by 300. FIG. 10 shows a head suspension assembly 308 including a load beam 312 having a base or mounting region 314 on a proximal end, a T-type flexure 316 on a distal end, a relatively rigid region 317 adjacent to the flexure, and a spring region 318 between the base 314 and the rigid region 317.

Flexure 316 includes a mounting portion 327, a pair of spaced arms 329*a* and 329*b* which extend from the mounting portion 327, and a cross member 331 which extends between the distal ends of arms 329*a* and 329*b*. The arms 329*a* and 329*b* and cross member 331 form gap 333 through the distal end of flexure 316. A tongue 334 extends from the cross member 331 into gap 333 toward load beam base 314. Cross member 331 is offset from arms 329*a* and 329*b* so the plane of the cross member 331 and tongue 334 are offset from the plane of the arms 329*a* and 329*b*. Tongue 334 also includes a conventional load point dimple 335. A slider (not shown) with a read/write head (not shown) is adhesively bonded or otherwise mounted to tongue 334 to form a head suspension assembly from suspension 308.

A microactuator 338 is positioned at the distal end of tongue 334 and is configured to move tongue 334 laterally between arms 329*a* and 329*b* in response to tracking control signals. The details of such a microactuator is disclosed in U.S. patent application Ser. No. 08/457,432 filed Jun. 6, 1995 by Jurgenson et al. for a Head Suspension with Tracking Microactuator. Any other suitable microactuator is also contemplated to be used in conjunction with the present invention. As microactuator 338 moves tongue 334, the read/write head (not shown) is moved beneath load point dimple 335 to be placed above a correct information track in a spinning magnetic disk (not shown).

As tongue 334 is moved between arms 329*a* and 329*b* the distal end of tongue 334 elastically deforms and causes strain in tongue 334. A strain transducer circuit 310, which acts as a strain gauge is located at the distal end of tongue 334. Individual transducer circuit lead 332 is configured to extend longitudinally back and forth in parallel sections connected at ends of the sections. As above, other configurations of circuit lead 332 are also within the ambit of the present invention. Lead wires 328*a* and 328*b* connect to opposite ends of transducer circuit 310 to form a continuous closed circuit between lead wires 328*a* and 328*b*. Lead wires 328*a* and 328*b* connect to contacts 330 on tab 326.

Deformation of the distal end of tongue 334 causes strain therein. This strain causes strain in circuit lead 332 and increasing the resistance of transducer circuit 310. The resistance of transducer circuit 310 can be detected across contacts 330 and may be converted into a voltage by a resistance to voltage transducer (not shown) such as a wheatstone bridge or other known means. This signal can then be provided to a servo controller (not shown) and even fed back to microactuator 338 to monitor the position of the read/write head over information tracks (not shown). Head suspension assembly 308 can be manufactured in a manner similar to that of head suspension assembly 8 shown in FIG. 1.

Though the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A head suspension assembly in which resonance mode motion can induce strain, the head suspension assembly comprising:

a load beam having a proximal end, a distal end, a mounting region on the proximal end, a rigid region adjacent to the distal end and a spring region between the rigid region and the mounting region;

a flexure for supporting a read/write head at the distal end of the load beam; and

at least one strain transducer circuit on the head suspension assembly for detecting strain therein such that the strain transducer circuit detects resonance mode motion of the head suspension assembly.

2. The head suspension assembly of claim 1 wherein the strain transducer circuit is located on the load beam.

3. The head suspension assembly of claim 1 wherein the load beam includes a spring region between the rigid region and the mounting region and further wherein the strain transducer circuit is located in the spring region.

4. The head suspension assembly of claim 1 wherein the strain transducer circuit is located on the rigid region of the load beam.

5. The head suspension assembly of claim 1 wherein the flexure includes a head attachment region for supporting a read/write head at the distal end of the load beam and wherein an elastic deformation of the head suspension assembly can displace the head attachment region from a neutral position and generate strain in the head suspension assembly.

6. The head suspension assembly of claim 5 wherein the strain transducer circuit has an electrical resistance which varies with strain in the head suspension assembly at a position of the strain transducer circuit thereon such that the resistance in the strain transducer circuit varies with deformation of the head suspension assembly to allow detection of motion of the head mounting region out of the neutral position.

7. The head suspension assembly of claim 6 wherein the strain transducer circuit is located on the load beam.

8. The head suspension assembly of claim 6 wherein the strain transducer circuit includes a single strain gauge lead having an electrical resistance that varies with strain on the lead.

9. The head suspension assembly of claim 8 wherein the strain gauge lead is formed of Constantan.

10. The head suspension assembly of claim 5 wherein the strain transducer circuit is located in the spring region.

11. The head suspension assembly of claim 10 including a first strain transducer circuit and a second strain transducer circuit wherein the spring region has an open region that divides the spring region into first and second radius arms and the first strain transducer circuit is located on the first radius arm and the second strain transducer circuit is located on the second radius arm.

12. The head suspension assembly of claim 1 wherein the strain transducer circuit is on the flexure.

13. The head suspension assembly of claim 1 including first, second, third and forth strain transducer circuits wherein the spring region has an open region that divides the spring region into first and second radius arms and the first and second strain transducer circuits are located on the first radius arm, the third and forth strain transducer circuits are located on the second radius arm, and the first, second, third and forth strain transducer circuits are interconnected to form a wheatstone bridge circuit.

14. A head suspension assembly comprising:

a load beam having a proximal end, a distal end, a mounting region on the proximal end, a rigid region adjacent to the distal end and a spring region between the rigid region and the mounting region;

a flexure having a head attachment region for supporting a read/write head and at the distal end of the load beam, the head attachment region displaceable from a neutral position, such displacement causing strain in the head suspension assembly;

a microactuator on the head suspension assembly between the mounting region and the head attachment region and to displace the head attachment region from the neutral position and along a transverse tracking axis; and

at least one strain transducer circuit on the head suspension assembly for detecting strain in the head suspension assembly wherein displacement of the head attachment region from the neutral position caused by the microactuator is detected by the strain transducer circuit.

15. The head suspension assembly of claim 14 wherein the strain transducer in located on the load beam.

16. The head suspension assembly of claim 14 wherein the strain transducer circuit has an electrical resistance which varies with strain in the head suspension assembly at a position of the strain transducer circuit thereon.

17. The head suspension assembly of claim 16 wherein the strain transducer circuit includes a single strain gauge lead having an electrical resistance that varies with strain on the lead.

18. A head suspension assembly in which resonance mode motion can induce strain, comprising:

a load beam having a proximal end, a distal end, a mounting region on the proximal end, a rigid region adjacent to the distal end and a spring region between the rigid region and the mounting region;

an actuator arm having a proximal end and a distal end, the proximal end of the load beam mounted to the distal end of the actuator arm;

a flexure for supporting a read/write head and at the distal end of the load beam; and

at least one strain transducer circuit on the head suspension assembly for detecting strain in the head suspension assembly such that the strain transducer circuit detects resonance frequency vibrations of the head suspension assembly.

19. The head suspension assembly of claim 18 wherein the strain transducer circuit has an electrical resistance which varies with strain in the head suspension assembly at a position of the strain transducer circuit thereon.

20. The head suspension assembly of claim 18 wherein the strain transducer circuit is located on the actuator arm.

21. The head suspension assembly of claim 18 including a first strain transducer circuit and a second strain transducer circuit wherein the first strain transducer circuit is located on the actuator arm and the second strain transducer circuit is located on the load beam.

* * * * *

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Novotny

(10) Patent No.: US 6,362,542 B1
(45) Date of Patent: *Mar. 26, 2002

(54) **PIEZOELECTRIC MICROACTUATOR FOR PRECISE HEAD POSITIONING**

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(73) Assignee: **Seagate Technology LLC**, Scotts Valley, CA (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/007,007**

(22) Filed: **Jan. 14, 1998**

Related U.S. Application Data

(60) Provisional application No. 60/055,874, filed on Aug. 15, 1997.

(51) **Int. Cl.**[7] **H02K 41/00**

(52) **U.S. Cl.** **310/12**; 310/328; 310/332; 360/104; 360/106; 360/109

(58) **Field of Search** 310/328, 330–332; 360/103, 106, 109, 104

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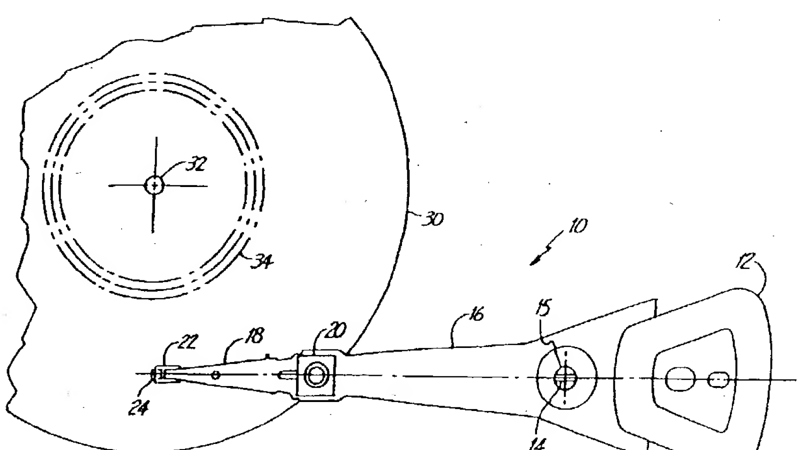
(74) *Attorney, Agent, or Firm*—Derek J. Berger; Jonathan E. Olson; Shawn B. Dempster

(57) **ABSTRACT**

A slider assembly for selectively altering a position of a transducing head with respect to a track of a rotatable disc having a plurality of concentric tracks includes a slider body having a main portion and a head portion separated by a gap. The head portion carries the transducing head. The slider body is arranged to be supported by a support structure over a surface of the rotatable disc. A pair of structural elements are disposed on opposite side surfaces of the slider body between the main portion and the head portion across the gap. At least one of the structural elements is a microactuator responsive to electrical control signals to selectively bend to alter the position of the head portion with respect to the main portion of the slider body. The structural elements may be complementary microactuators. The microactuators may be formed by a process involving forming the microactuators on a slider substrate or on a row of sliders, forming the microactuators on a slider stack, or separately forming the microactuators and attaching the microactuators to a slider stack.

13 Claims, 11 Drawing Sheets



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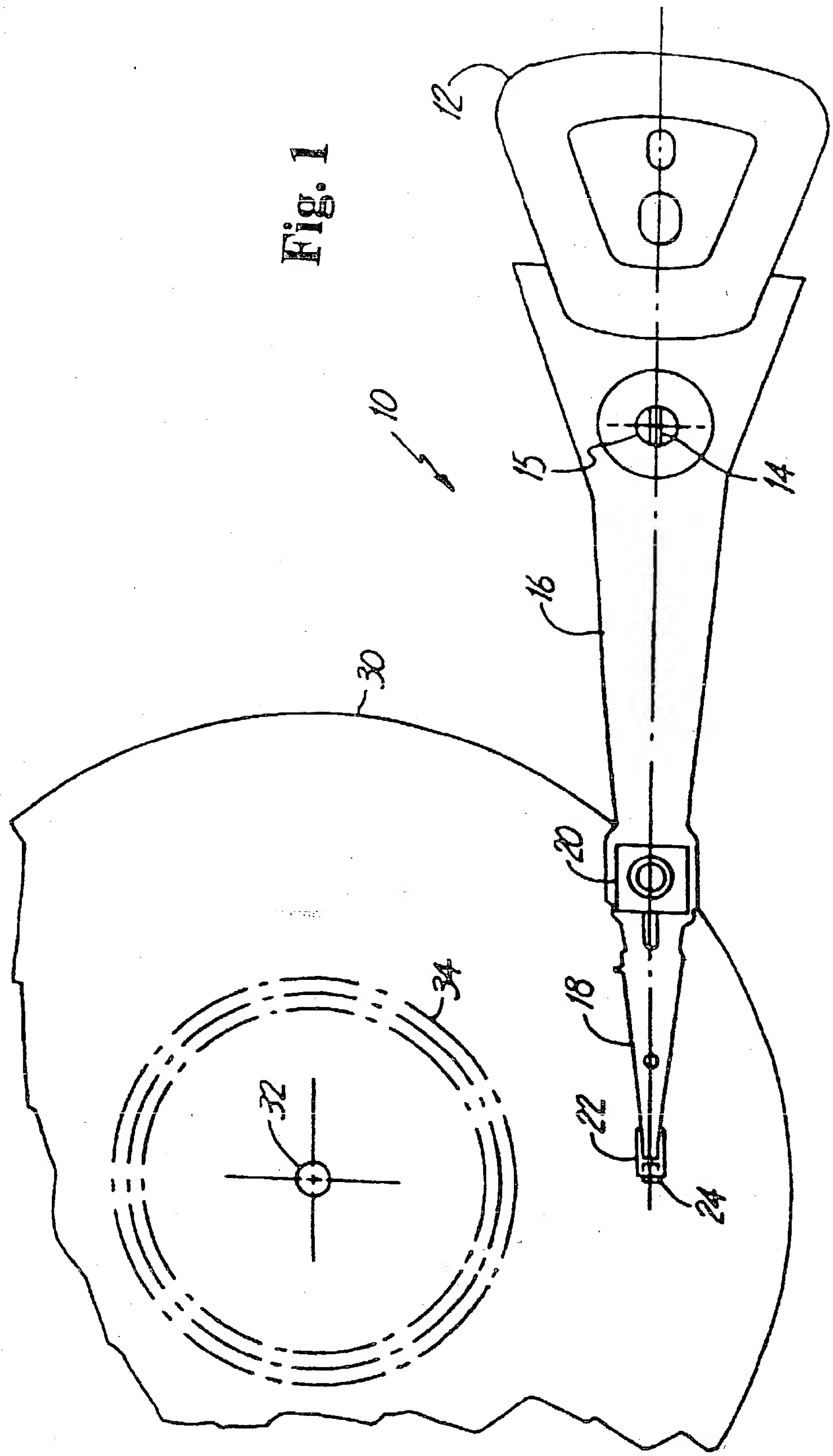


Fig. 1

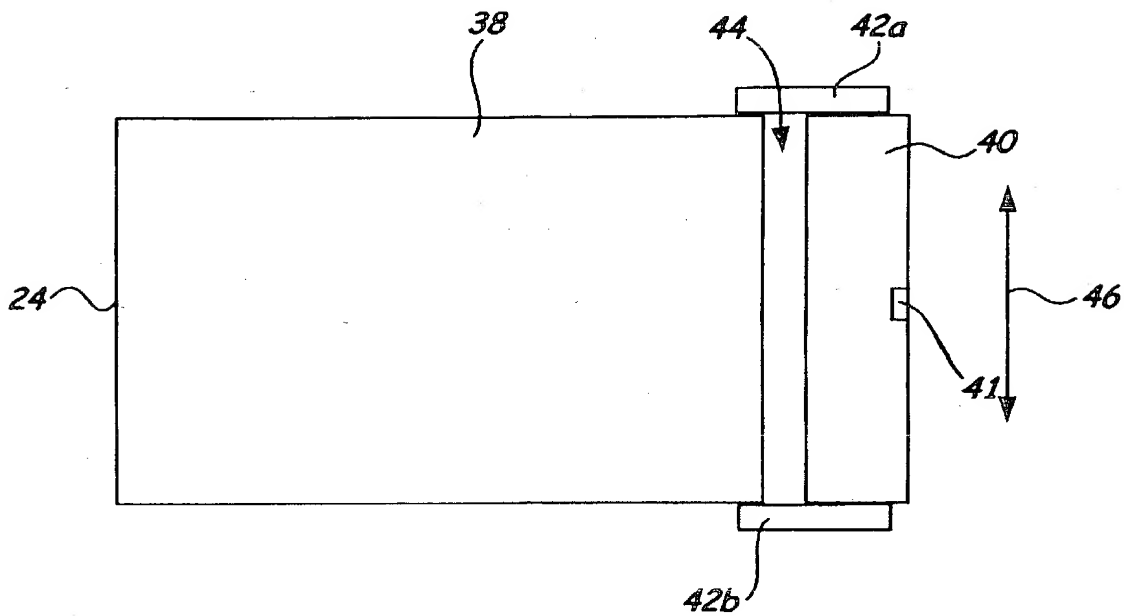


Fig. 2

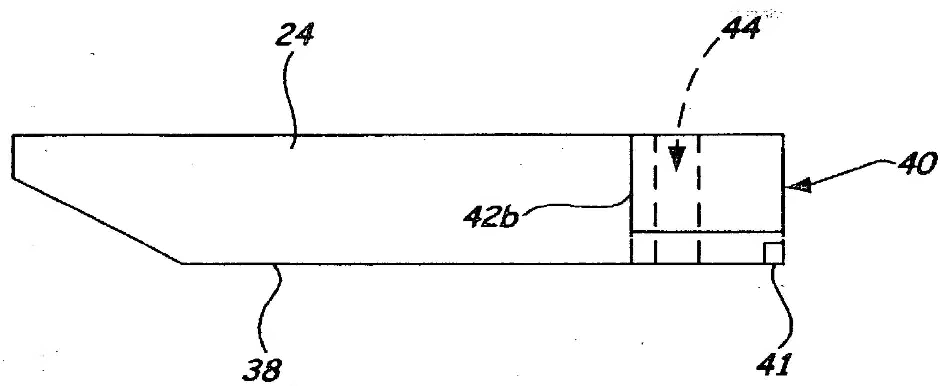


Fig. 3

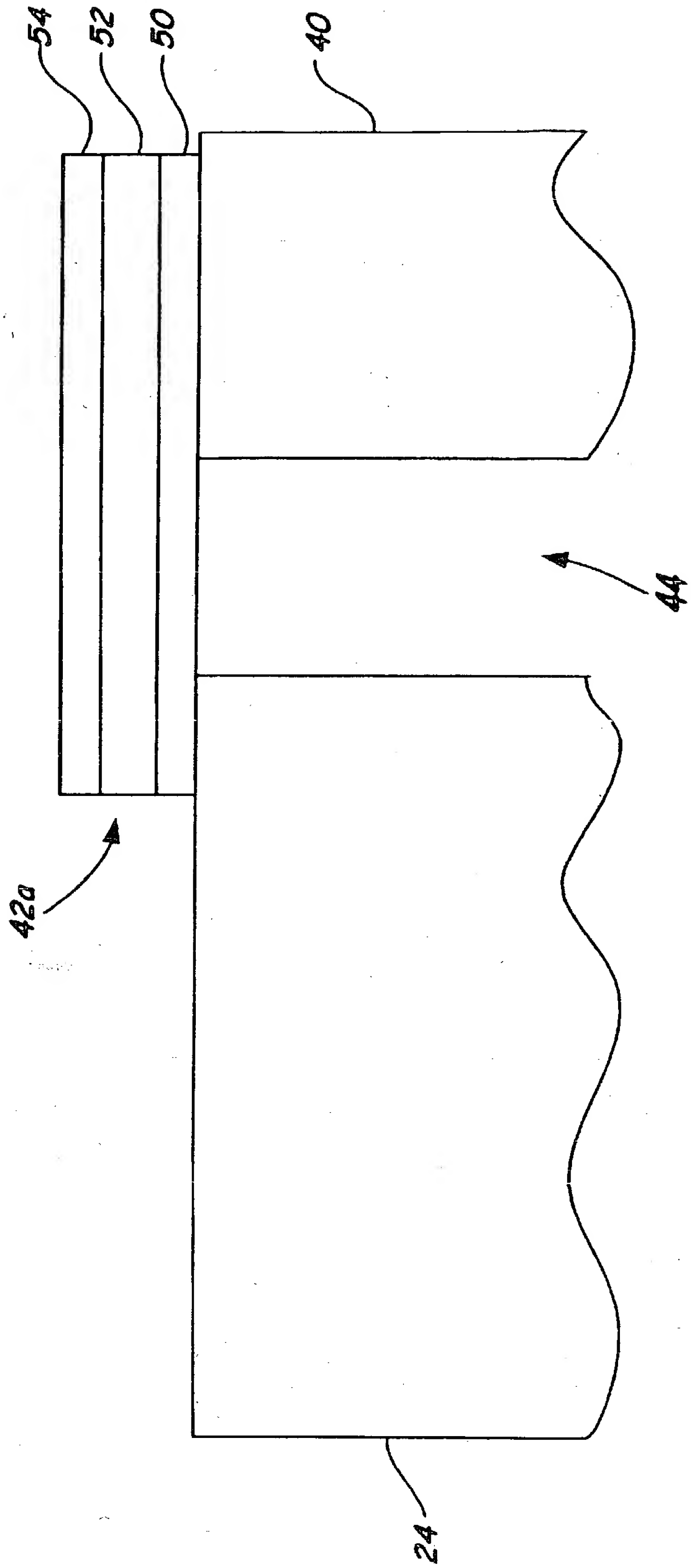


Fig. 4

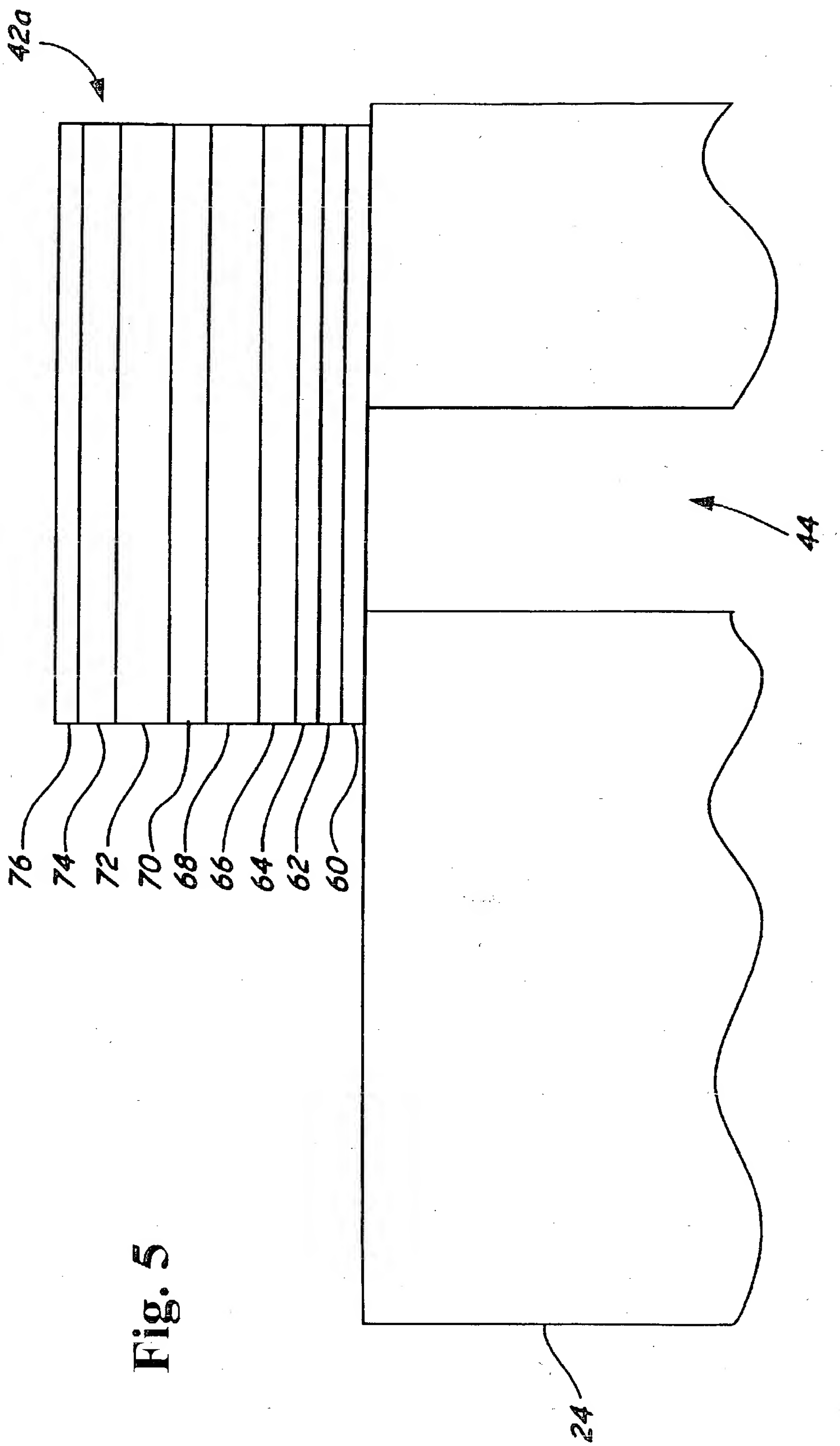


Fig. 5

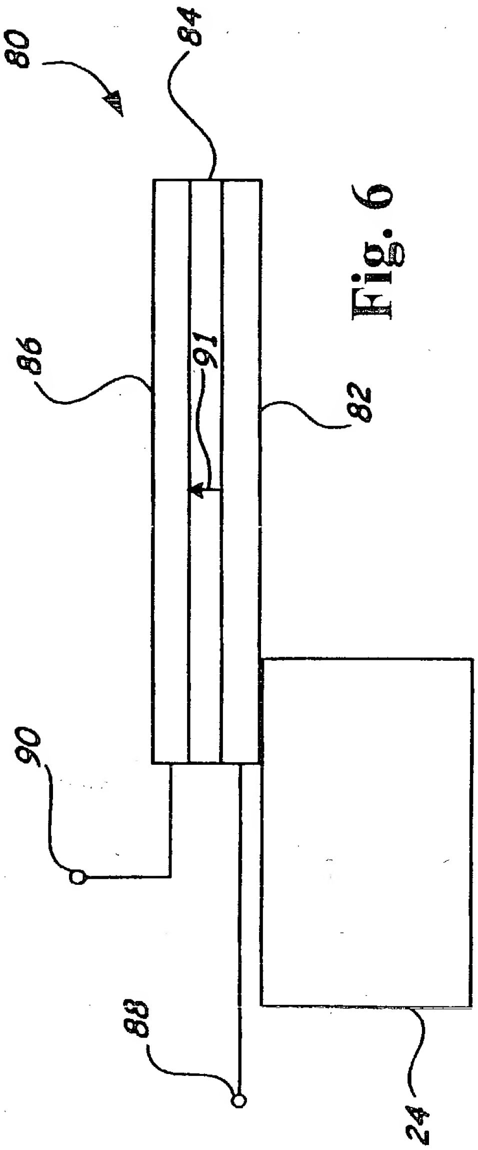


Fig. 6

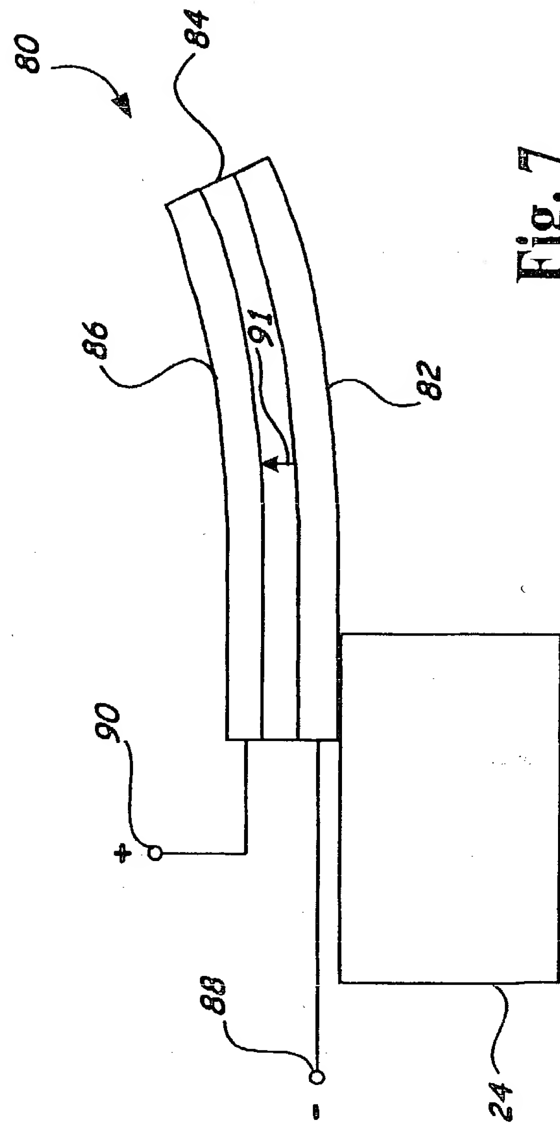
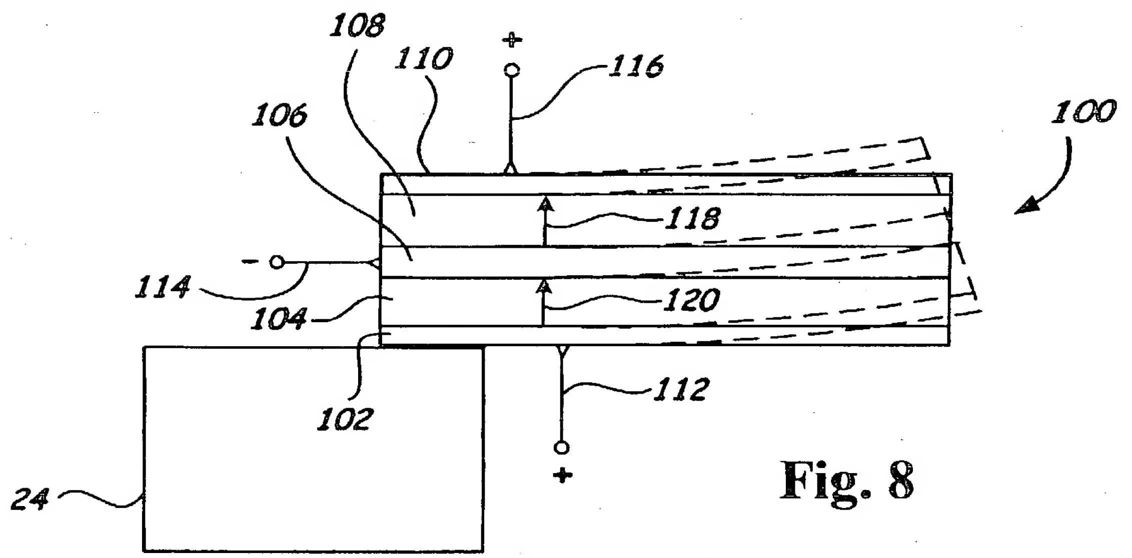


Fig. 7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110
+
116
106
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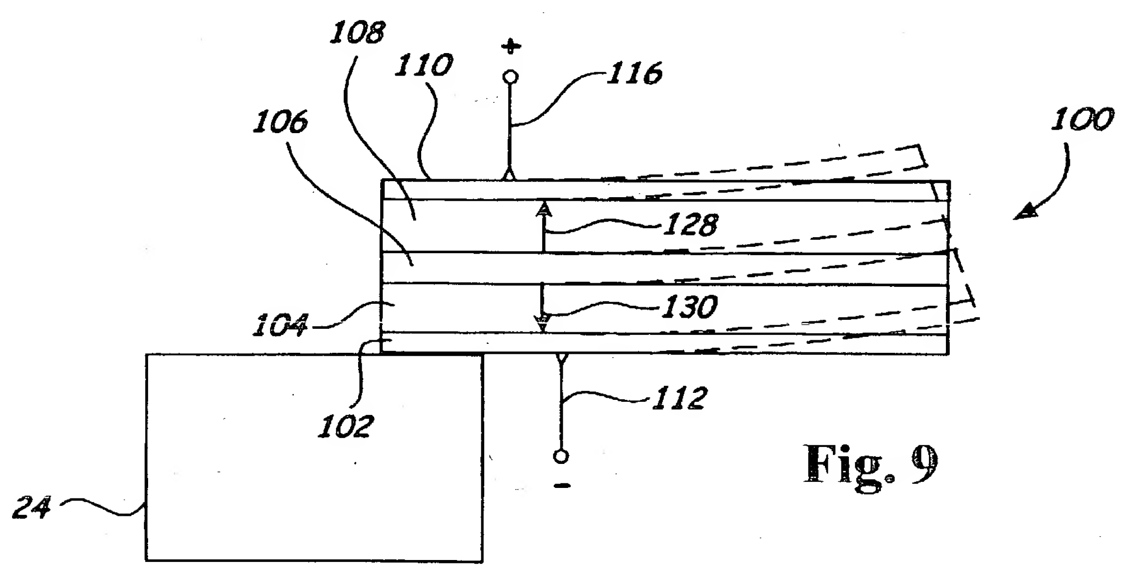
118
-
114
120
104
102
112
+
24

Fig. 8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112
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24

Fig. 9

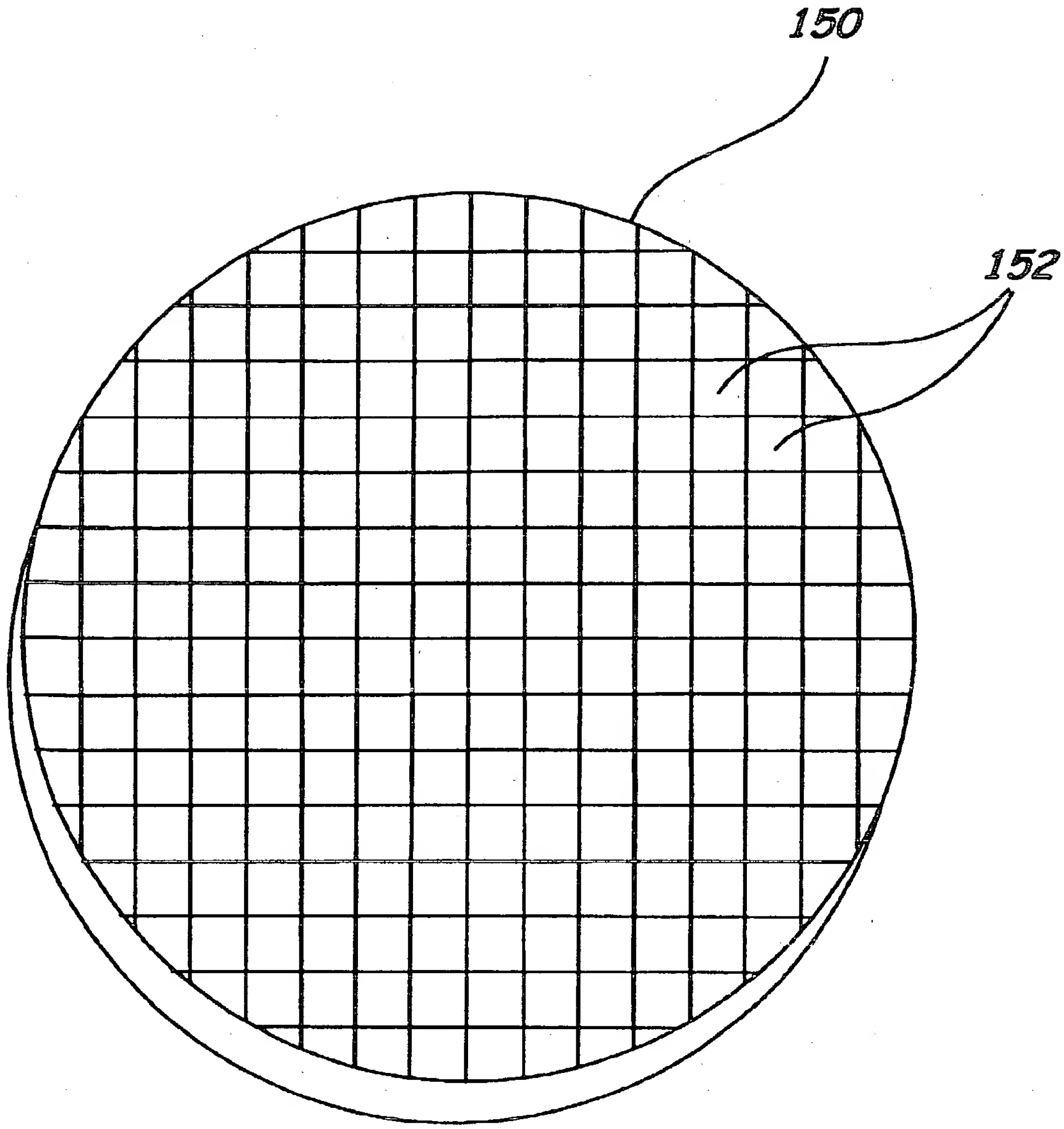

Fig. 10

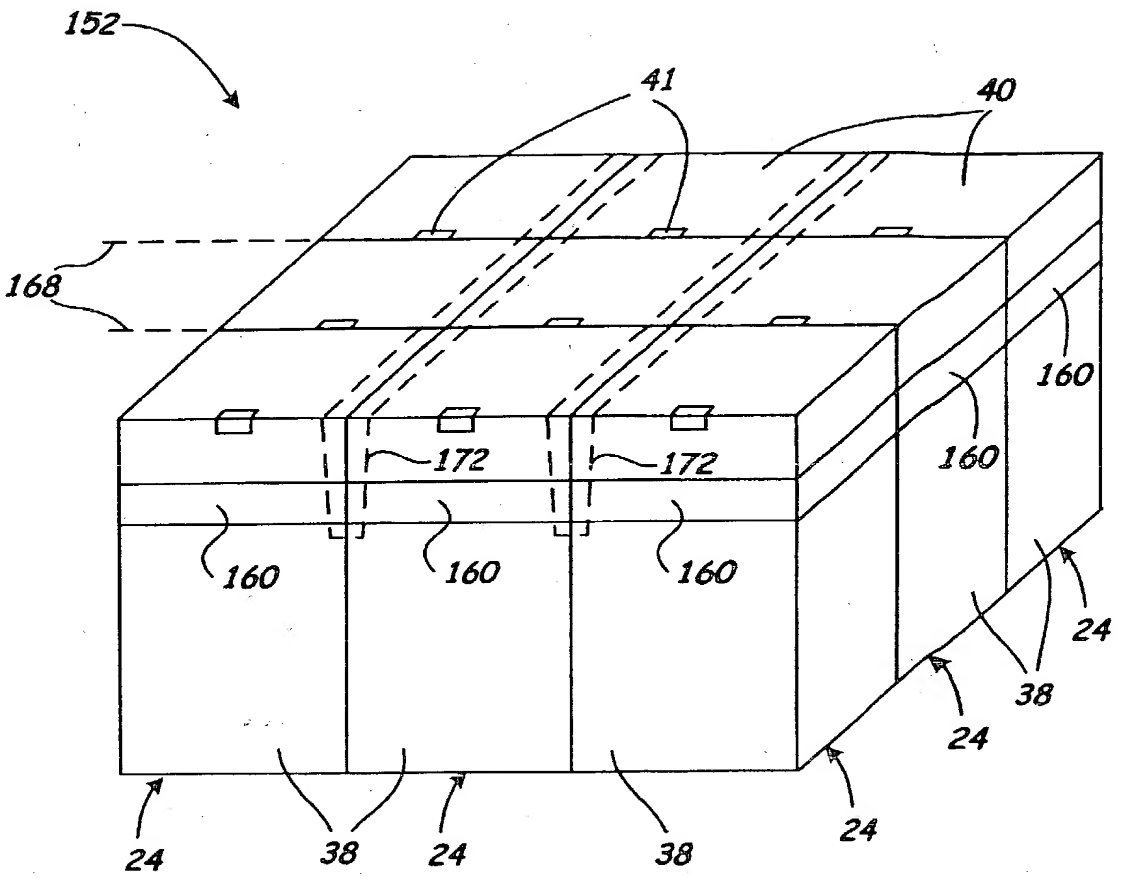
152
41
40
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Fig. 11

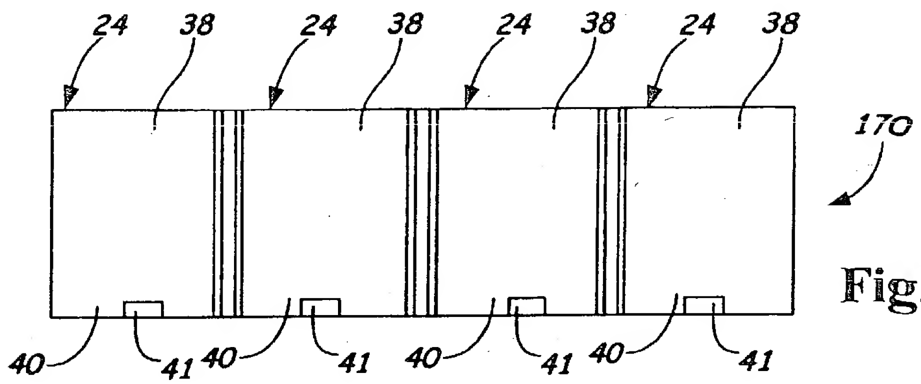
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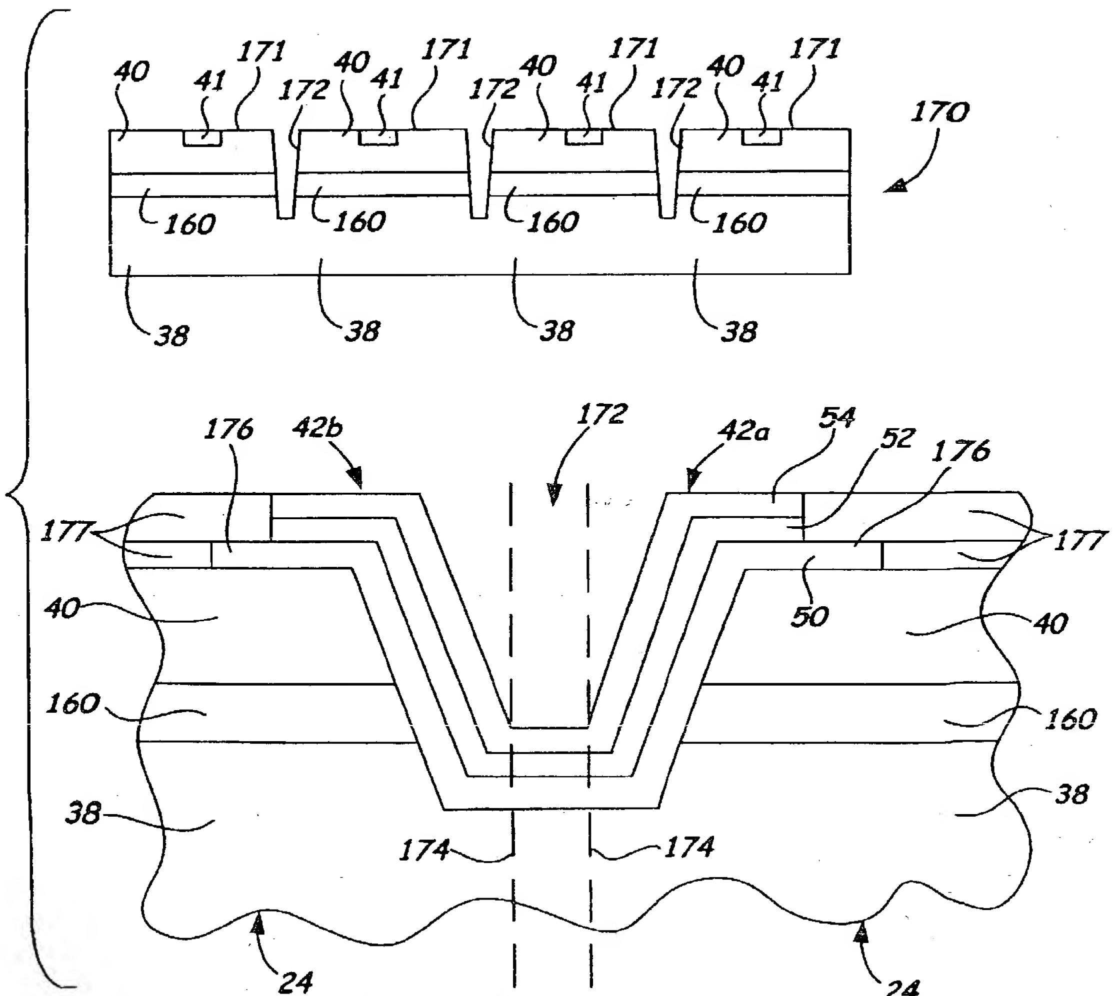
Fig. 12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42b
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42a
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174
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24

Fig. 13

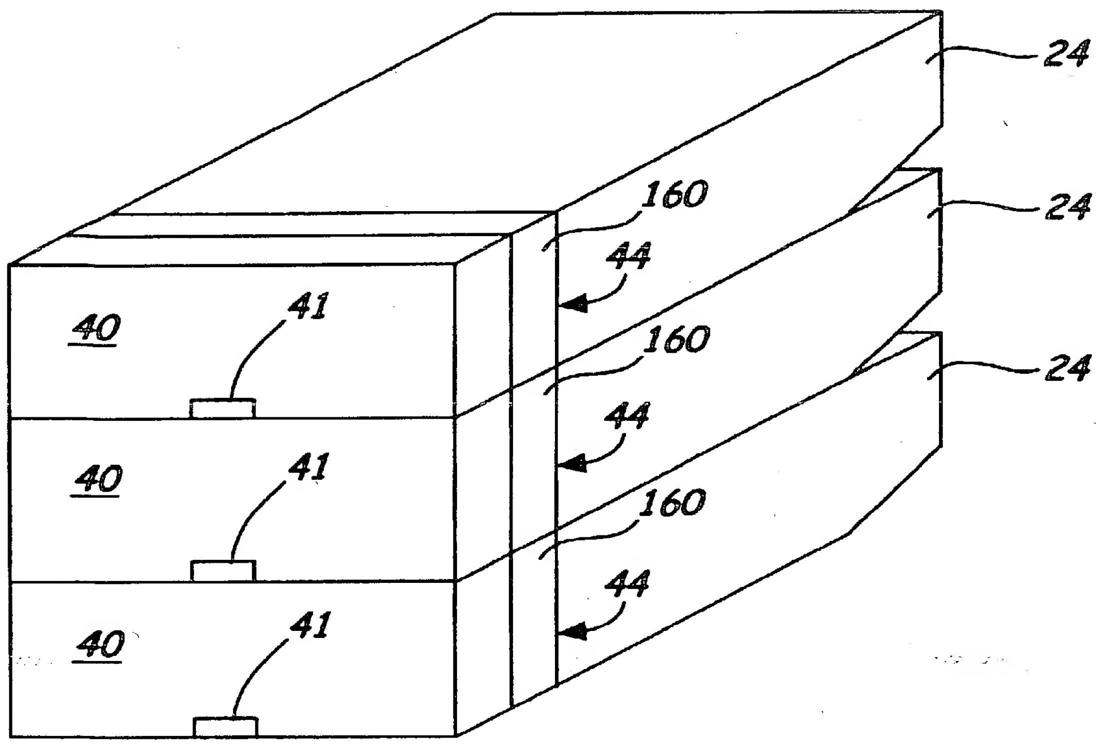

Fig. 14

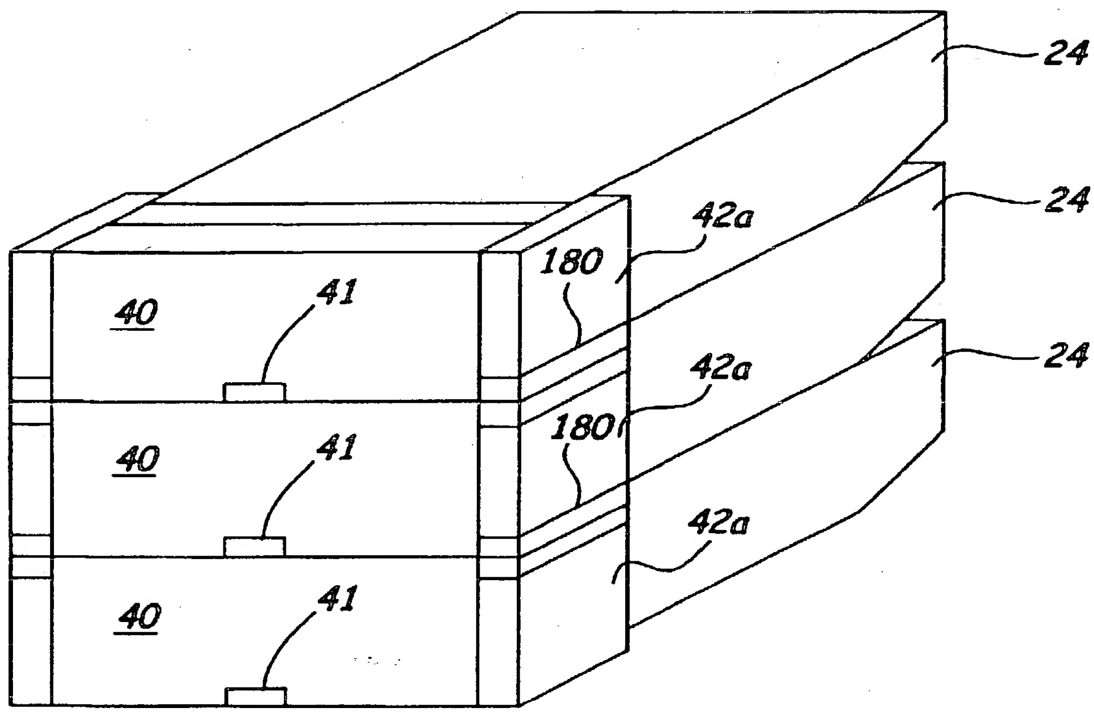

Fig. 15

PIEZOELECTRIC MICROACTUATOR FOR PRECISE HEAD POSITIONING

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority from Provisional Application No. 60/055,874 filed Aug. 15, 1997 for "Piezoelectric Head Moving Microactuator For Ultrahigh Track Density Magnetic Recording Drives" by V. Novotny.

BACKGROUND OF THE INVENTION

The present invention relates to a disc drive microactuator, and more particularly to a high resolution head positioning mechanism having one or more piezoelectric elements attached to a slider as a bendable cantilever for selectively moving a head portion of the slider radially with respect to circumferential data tracks of a rotatable disc.

The track density, or radial spacing, between concentric data tracks on magnetic discs continues to increase, requiring greater precision in head positioning. Conventionally, head positioning is accomplished by operating an actuator arm with a large-scale actuator motor, such as a voice coil motor, to position a head on a flexure at the end of the actuator arm. The large-scale motor lacks sufficient resolution and bandwidth to effectively accommodate high track-density discs. Thus, a high resolution head positioning mechanism is necessary to accommodate the more densely spaced tracks.

One promising design for high resolution head positioning involves employing a high resolution microactuator in addition to the conventional low resolution actuator motor, thereby effecting head positioning through dual-stage actuation. Various microactuator designs have been considered to accomplish high resolution head positioning, including piezoelectric, electromagnetic, electrostatic, capacitive, fluidic, and thermal actuators. Various locations for the microactuator have been suggested, including on the slider, on the gimbal, at the interface between the gimbal and the slider, and on the actuator arm, for example. However, the previous designs all had shortcomings that limited the effectiveness of the microactuator, such as substantial performance limitations or manufacturing complexities, which made the microactuator designs impractical. An effective microactuator design must provide high acceleration in positioning the head while also generating sufficiently large and accurate displacements to precisely move the head across several data tracks on the disc.

There is a need in the art for a microactuator design to provide high resolution head positioning with superior bandwidth performance characteristics that can be implemented by simple and readily available manufacturing processes.

BRIEF SUMMARY OF THE INVENTION

The present invention is a slider assembly for selectively altering a position of a transducing head with respect to a track of a rotatable disc having a plurality of concentric tracks. The slider assembly includes a slider body having a main portion and a head portion separated by a gap. The head portion carries the transducing head. The slider body is arranged to be supported by a support structure over a surface of the rotatable disc. A pair of structural elements are disposed on opposite side surfaces of the slider body between the main portion and the head portion across the gap. At least one of the structural elements is a microactuator responsive to electrical control signals to selectively bend to alter the position of the head portion with respect to the main portion of the slider body. The structural elements are preferably complementary microactuators.

Another aspect of the present invention is a process of forming a pair of microactuators on each of a plurality of sliders. A slider substrate is formed comprising main portions of the sliders, and a sacrificial layer is deposited on the slider substrate. Head portions each carrying a transducing head are then formed on the sacrificial layer. A row of sliders is separated from the slider substrate, an air-bearing surface is formed on each of the sliders in the row, and notches are cut between individual sliders in the row. Microactuators are formed between the main portions and the head portions of the sliders on side surfaces of the sliders in the notches. Alternatively, the microactuator processing may be performed at the wafer level, prior to the steps of separating the slider substrate into rows and defining the air-bearing surfaces of the sliders in the rows. Individual sliders are separated from the slider row such that a pair of microactuators are on opposite side surfaces of each of the sliders. The sacrificial layer is removed to form a gap between the main portions and the head portions of the sliders.

A further aspect of the present invention is a process of forming a microactuator on each of a plurality of sliders. A slider substrate is formed comprising main portions of the sliders, and a sacrificial layer is deposited on the slider substrate. Head portions each carrying a transducing head are then formed on the sacrificial layer. A row of sliders is separated from the slider substrate, and an air-bearing surface is shaped for each of the sliders in the row. Individual sliders are separated from the row of sliders, and a plurality of the individual sliders are glued together to form a slider stack. A plurality of microactuators are formed on side surfaces of each of the sliders in the slider stack, and the sacrificial layer is etched away to form a gap between the main portions and head portions of each of the sliders. The sliders are separated from each other by dissolving the glue. Alternatively, the plurality of microactuators may be separately formed and attached to the side surfaces of the sliders stack, and then separated into individual microactuators for each of the sliders in the slider stack.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top view of a disc drive actuation system for positioning a slider over tracks of a disc.

FIG. 2 is a top view of a slider including piezoelectric microactuators for high resolution head positioning according to the present invention.

FIG. 3 is a side view of the slider shown in FIG. 2.

FIG. 4 is an enlarged top view of a portion of the slider shown in FIG. 2 illustrating the construction of the piezoelectric microactuator according to a first embodiment of the present invention.

FIG. 5 is an enlarged top view of a portion of the slider shown in FIG. 2 illustrating the construction of the piezoelectric microactuator according to a second embodiment of the present invention.

FIG. 6 is a diagram illustrating a unimorph piezoelectric bending motor in its neutral position.

FIG. 7 is a diagram illustrating the unimorph piezoelectric bending motor of FIG. 6 in its actuated position.

FIG. 8 is a diagram illustrating a bimorph piezoelectric bending motor configured for parallel operation.

FIG. 9 is a diagram illustrating a bimorph piezoelectric bending motor configured for series operation.

FIG. **10** is a diagram of a typical slider substrate wafer.

FIG. **11** is a perspective view of a portion of the substrate wafer shown in FIG. **10** in enlarged detail, illustrating a process according to a third embodiment of the present invention.

FIG. **12** is a top view of a slider row processed according to a fourth embodiment of the present invention.

FIG. **13** is a side view of the slider row shown in FIG. **12**, with a portion shown in enlarged detail to illustrate the microactuator.

FIG. **14** is a perspective view of a stack of sliders on which to form piezoelectric microactuators according to a fifth embodiment of the present invention.

FIG. **15** is a perspective view of the stack of sliders shown in FIG. **10** with piezoelectric microactuators formed thereon according to the fifth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a top view of a disc drive actuation system **10** for positioning slider **24** over a track **34** of disc **30**. Actuation system **10** includes voice coil motor (VCM) **12** arranged to rotate actuator arm **16** around axis **14**. Head suspension **18** is connected to actuator arm **16** at head mounting block **20**. Flexure **22** is connected to an end of head suspension **18**, and carries slider **24**. Slider **24** carries a transducing head (not shown in FIG. **1**) for reading and/or writing data on concentric tracks **34** of disc **30**. Disc **30** rotates around axis **32**, so that windage is encountered by slider **24** to keep it aloft a small distance above the surface of disc **30**.

VCM **12** is selectively operated to move actuator arm **16** around axis **14**, thereby moving slider **24** between tracks **34** of disc **30**. However, for disc drive systems with high track density, VCM **12** lacks sufficient resolution and frequency response to position a transducing head on slider **24** over a selected track **34** of disc **30**. Therefore, a higher resolution actuation device is necessary.

FIG. **2** is a top view and FIG. **3** is a side view of slider **24** including piezoelectric microactuator **42*a*** and structural element **42*b*** to enable high resolution positioning of head **41** according to the present invention. Slider **24** includes a head portion **40** carrying transducing head **41** and also includes air gap or space **44** between head portion **40** of slider **24** and the remaining portion of slider **24**. Microactuator **42*a*** and structural element **42*b*** are disposed on the side surfaces of slider **24** near its distal end, connecting head portion **40** to the remainder of slider **24**. Microactuator **42*a*** is a structural element operable as a bendable cantilever to alter the position of head portion **40** with respect to main portion **38**. Structural element **42*b*** is preferably a microactuator similar and complementary to microactuator **42*a***, but may alternatively be a layer of structural material such as silicon nitride (Si_3N_4) or polysilicon, for example, to provide some flexibility while prevent undesired vibrations that could affect the position of transducing head **41**. Transducing head **41** comprises an inductive write head and/or a magnetoresistive read head, for example, as is well known in the art. Transducing head **41** is desirably positioned directly over a data track on a rotating disc to read and/or write data from and/or to the disc.

In operation, slider **24** is coarsely positioned adjacent a selected data track by activating VCM **12** to move actuator arm **16** (FIG. **1**) carrying slider **24**. To finely position transducing head **41** over the selected track, control signals are applied to piezoelectric microactuator **42*a*** to cause bending of microactuator **42*a*** and consequent bending of structural element **42*b***. When structural element **42*b*** is a microactuator, control signals are also applied to microactuator **42*b*** to cause bending complementary to microactuator **42*a***. Bending of microactuators **42*a*** and **42*b*** is controlled to selectively alter the position of transducing head **41** in the direction of arrows **46**, thereby precisely positioning transducing head **41** directly over the selected track on the disc.

FIG. **4** is an enlarged top view of the distal portion of slider **24** illustrating the construction of piezoelectric microactuator **42*a*** according to a first embodiment of the invention. Bottom electrode **50** connects head portion **40** to the remainder of slider **24** across gap **44**. Piezoelectric element **52** is formed on bottom electrode **50**, and top electrode **54** is formed on piezoelectric element **52**. This configuration forms a cantilevered unimorph piezoelectric bending motor, the operation of which is described in detail below with respect to FIGS. **6** and **7**.

FIG. **5** is an enlarged top view of the distal portion of slider **24** illustrating the construction of piezoelectric microactuator **42*a*** according to a second embodiment of the invention. Structural layer **60** connects head portion **40** to the remainder of slider **24** across gap **44**. Buffer layer **62** is formed on structural layer **60**, and adhesive layer **64** is disposed on buffer layer **62**. Bottom electrode **66** is formed on adhesive layer **64**, and first piezoelectric element **68** is formed on bottom electrode **66**. Shared electrode **70** is formed on piezoelectric element **68**. A second piezoelectric element **72** is formed on shared electrode **70**, and top electrode **74** is formed on piezoelectric element **72**. An optional encapsulation layer **76** is formed over top electrode **74**. This configuration of piezoelectric microactuator **42*a*** forms a bimorph piezoelectric bending motor, the operation of which is discussed in detail later with respect to FIGS. **8** and **9**.

In an exemplary embodiment, structural layer **60** is composed of silicon nitride (Si_3N_4) or polysilicon. Buffer layer **62** is preferably composed of silicon dioxide (SiO_2) or titanium dioxide (TiO_2). Adhesive layer **64** is preferably composed of titanium (Ti) or tantalum (Ta). Bottom electrode **66**, shared electrode **70** and top electrode **74** are preferably formed of platinum (Pt). Piezoelectric elements **68** and **72** may be composed of zinc oxide (ZnO), lead zirconium titanate ($PbZrTiO_3$, known as PZT), aluminum nitride (AlN) or polyvinylidene fluoride (PVDF). The zinc oxide material requires no annealing or low temperature annealing, while the PZT material requires high temperature annealing. Piezoelectric elements **68** and **72** may be deposited by sputtering, sol gel techniques or laser deposition, as is known in the art.

FIG. **6** is a diagram of a cantilevered unimorph bending motor **80** in its neutral position, and FIG. **7** is a diagram of cantilevered unimorph bending motor **80** in its actuated position. Unimorph bending motor **80** may be implemented by piezoelectric microactuator **42*a*** described above with respect to FIG. **4**. Unimorph bending motor **80** includes bottom electrode **82**, piezoelectric element **84** and top electrode **86**, and is restrained at one end by connection to a solid object such as slider **24**. Terminal **88** connects bottom electrode **82** to a first potential and terminal **90** connects top electrode **86** to a second potential. Piezoelectric element **84** is poled in the direction indicated by arrow **91**.

In operation, when the potential difference between terminals **88** and **90** (and consequently between bottom electrode **82** and top electrode **86**) is applied across piezoelectric element **84**, the element contracts along its length, forcing

bending of piezoelectric element 84 and electrodes 82 and 86 as indicated in FIG. 7. In this way, a deflection at the distal tip of bending motor 80 may be achieved. Conversely, application of an opposite potential difference between terminals 88 and 90 across piezoelectric element 84 results in opposite bending and opposite deflection at the distal tip of bending motor 80.

FIG. 8 is a diagram illustrating a cantilevered bimorph piezoelectric bending motor 100 configured for parallel operation. Bimorph piezoelectric bending motor 100 may be implemented by piezoelectric microactuator 42*a* described above with respect to FIG. 5. Bimorph piezoelectric bending motor 100 is restrained at one end by connection to a solid object such as slider 24. Bimorph piezoelectric bending motor 100 includes bottom electrode 102, first piezoelectric element 104, shared electrode 106, second piezoelectric element 108, and top electrode 110. In the "parallel" configuration depicted in FIG. 8, piezoelectric elements 104 and 108 are poled in the direction of arrows 118 and 120. A first voltage is applied at terminal 112 to bottom electrode 102, and at terminal 116 to top electrode 110. A second voltage is applied at terminal 114 to shared electrode 106. Thus, in the "parallel" configuration, piezoelectric element 108 will contract, and piezoelectric element 104 will expand, in response to the first and second voltages applied at the terminals. The result is a bending motion (shown in dashed lines) of bimorph piezoelectric bending motor 100, since one end of the motor is restrained by connection to slider 24. The amount of bending of the motor, and thus the amount of displacement of transducing head 41 on head portion 40 (FIG. 2) is precisely controlled by the voltages applied to terminals 112, 114 and 116. Applying opposite voltages to terminals 112, 114 and 116 causes similar bending in the opposite direction. Thus, bimorph piezoelectric bending motor 100 is able to provide high resolution positioning of head 41 over a selected track of a disc.

FIG. 9 is a diagram illustrating a cantilevered bimorph piezoelectric bending motor 100 configured for series operation. Bimorph piezoelectric bending motor 100 may be implemented by piezoelectric microactuator 42*a* described above with respect to FIG. 5. Just as in FIG. 8, bimorph piezoelectric bending motor 100 includes bottom electrode 102, first piezoelectric element 104, shared electrode 106, second piezoelectric element 108, and top electrode 110. Piezoelectric element 108 is poled in the direction of arrow 128 and piezoelectric element 104 is poled in the opposite direction, shown by arrow 130. A first voltage is applied at terminal 116 to piezoelectric element 108, and a second voltage is applied at terminal 112 to piezoelectric element 104. As a result, bimorph piezoelectric bending motor 100 bends as indicated in dashed lines, since one end of the motor is restrained by the connection to slider 24. Applying opposite voltages to terminals 112 and 116 causes similar bending in the opposite direction. The "series" configuration is the simplest and most economical, since it requires only two connections to the outside surfaces of piezoelectric elements 104 and 108. However, the "series" configuration yields less deflection per volt of applied potential than the "parallel" configuration shown in FIG. 8. The "parallel" configuration is more complex, requiring three electrical connections, the additional connection being made to shared electrode 106. Either of the configurations shown in FIGS. 8 and 9 are acceptable for effecting high resolution positioning of transducing head 41 (FIG. 2) over a selected track of a disc.

FIG. 10 is a diagram of a typical slider substrate wafer 150. Substrate wafer 150 is shown to comprise a plurality of portions 152 used to form a plurality of sliders 24, and has a thickness equal to a desired length of the sliders.

FIG. 11 is a perspective view of a portion 152 of substrate wafer 150. The portion 152 shows a 3×3 array of sliders 24. Transducing heads 41 are formed on the top (trailing edge) surface of each slider 24 of wafer 150, as is known in the art. The portion 152 further has layers formed thereon according to the present invention. In order to form sliders 24 with a gap between main portions 38 and head portions 40, the substrate wafer is used to define only main portions 38 of sliders 24. Sacrificial layer 160 is deposited on the substrate wafer to define the region that will become the gap.

According to a third embodiment of the present invention, notches 172 are cut between columns of sliders 24 before wafer 150 is cut (along dotted lines 168) into slider rows. After notches 172 have been cut, multilayer piezoelectric microactuators are formed in notches 172. The details of the process of forming the microactuators essentially identical to the process discussed below with respect to FIG. 13, with long strips of materials being formed for several sliders rather than forming individual microactuators for each slider. Wafer 150 is then ready to be diced into slider rows along dotted lines 168, at which point the air-bearing surfaces of sliders 24 are formed.

FIG. 12 is a top view, and FIG. 13 is a side view with a portion shown in enlarged detail, of a slider row 170 processed according to a fourth embodiment of the present invention, with structural elements 42*b* being implemented as microactuators. Slider row 170 includes a plurality of sliders 24 each having an air-bearing surface 171 and notches 172 cut between sliders 24. Notches 172 are shown as trapezoidal in shape, which facilitates sidewall deposition of microactuator layers between sliders; alternatively, notches 172 may be right-angle cuts if more sophisticated sidewall deposition techniques are employed. Notches 172 are cut by a diamond saw, for example, and preferably do not extend through the entire height of sliders 24, so that sliders 24 remain attached to one another in slider row 170.

Microactuators 42*a* and 42*b* are formed in notches 172 on opposite sides of sliders 24. Photolithography is performed to define the regions where the electrodes and piezoelectric materials of microactuators 42*a* and 42*b* are to be deposited, with photoresist layers 177 being deposited to protect transducing head 41. Bottom electrode 50 is then deposited in notch 172, also extending onto the top surface of sliders 24. Piezoelectric element 52 is deposited and annealed on bottom electrode 50. If high annealing temperatures are required that are incompatible with the materials in transducing heads 41 of sliders 24, annealing may be performed by a localized laser heating process, for example. Preferably, piezoelectric element 52 is composed of a material that does not require annealing temperatures that are incompatible with heads 41. Top electrode 54 is then deposited on piezoelectric element 52, and poling of piezoelectric element 52 is performed at an elevated temperature. Bottom electrode 50 preferably extends on the top surface of sliders 24 beyond piezoelectric element 52 and top electrode 54 at regions 176, to provide easy access to bottom electrode 50 for electrical connection thereto. After bottom electrode 50, piezoelectric element 52 and top electrode 54 have been deposited, photoresist layers 177 used in the photolithography process to define the microactuator regions and protect transducing head 41 are removed and sliders 24 are separated from slider row 170 by dicing at lines 174. Sacrificial layer 160 between main portions 38 and head portions 40 of sliders 24 is also etched away to form the gap between those portions. Electrical connections are made to the microac-

tuator in a manner known in the art, such as through the flex circuit used to contact transducing head **41**, and may be made on the top of the slider or on any other exposed surfaces of bottom electrode **50** and top electrode **54**. Although microactuators **42***a* and **42***b* are only shown in FIG. **13** with bottom electrode **50**, piezoelectric element **52** and top electrode **54** (as described above with respect to FIG. 4), it should be understood that microactuators **42***a* and **42***b* may be formed to include the layers described above with respect to FIG. 5.

FIGS. **14** and **15** are perspective views of a stack of sliders **24**, illustrating a process of forming microactuator **42***a* and structural element **42***b* on sliders **24** according to a fifth embodiment of the present invention. Sliders **24** are each formed as described above with respect to FIGS. **11** and **12** by initially forming main portions **38** of sliders **24**, depositing sacrificial layer **160** on the distal surface of main portions **38**, and forming head portions **40** on sacrificial layer **160**, with head portions **40** carrying transducing heads **41**. Sacrificial layer **160** occupies the area that will become gap regions **44** between main portions **38** of sliders **24** and head portions **40**. Sliders **24** are diced apart and then stacked and glued together lightly. Piezoelectric microactuator **42***a* and structural element **42***b* (which is preferably another microactuator) are either formed directly on slider row assemblies, with the microactuator areas defined by photolithography, for example, on side surfaces of the slider stack, or are separately formed in strips or sheets and then attached to the side surfaces of the slider stack, yielding the structure shown in FIG. **15**. Microactuator **42***a* may be formed on a structural layer (such as layer **60** in FIG. **5**) deposited on the side surfaces of the slider stack, or may be formed or attached directly on the side surfaces of the stack. Structural element **42***b* may be a microactuator similar and complementary to microactuator **42***a*, or may be a structural layer composed of silicon nitride (S_3N_4) or polysilicon, for example. Where the layers of microactuators **42***a* and **42***b* are formed as sheets or strips along the side surfaces of the slider stack, the material layers are cut at regions **180** so that microactuators **42***a* and **42***b* do not extend all the way to the air-bearing surfaces of sliders **24**. In the case where microactuator **42***a* and structural element **42***b* are formed on a separate substrate (which is subsequently removed) and attached to the slider stack, the multilayer sheets are ultimately separated into individual microactuators on each of the sliders **24** by a laser, for example. This separate formation and transfer process avoids potential temperature incompatibilities, since the potentially high temperature annealing of the piezoelectric material is not performed proximate to transducing head **41**. Sacrificial layer **160** is then etched away to form gaps **44** between the main portions of sliders **24** and head portions **40** of the sliders. The glue holding sliders **24** together is then dissolved, leaving each individual slider with piezoelectric microactuator **42***a* and structural element **42***b* on its side surfaces across gap **44**. Alternatively, the process described above could be performed on each slider individually, thereby increasing the number of steps involved to attach the microactuators to the sliders but eliminating the steps of initially gluing the sliders together, separating the microactuators and ultimately dissolving the glue to separate the sliders.

The present invention provides precise, high performance head positioning, with high acceleration in moving the head and sufficiently large and accurate head displacement to cover several data tracks. Only head portion **40** of slider **24** is moved by microactuator **42***a* (and structural element **42***b*, when it is implemented as a microactuator), minimizing the total mass that is displaced and thereby enabling high acceleration of head **41**. Additionally, moving only head portion **40** of slider **24** allows the microactuator to cancel resonance effects associated with the actuator arm and flexure, eliminating any track misregistration effects due to vibrations or the like resulting from those resonances. The microactuators are also readily manufacturable by simple existing fabrication techniques with only the addition of a sacrificial layer on the slider, minimizing the incremental cost of the microactuator-equipped disc drive.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A disc drive slider and transducing head assembly for selectively altering a position of the transducing head with respect to a track of a rotatable disc having a plurality of concentric tracks, comprising:

a slider body having a discrete main portion and a discrete head portion separated by a gap, the head portion carrying the transducing head, the slider body being arranged to be supported by a support structure over a surface of the rotatable disc; and

means for connecting the head portion to the main portion of the slider body and for selectively altering the position of the head portion with respect to the main portion of the slider body.

2. A disc drive slider and transducing head assembly for selectively altering a position of the transducing head with respect to a track of a rotatable disc having a plurality of concentric tracks, comprising:

a slider body having a discrete main portion and a discrete head portion separated by a gap, the head portion carrying the transducing head, the slider body being arranged to be supported by a support structure over a surface of the rotatable disc; and

a pair of structural elements on opposite side surfaces of the slider body between the main portion and the head portion across the gap, at least one of the structural elements being a microactuator responsive to electrical control signals to selectively bend to alter the position of the head portion with respect to the main portion of the slider body.

3. The slider assembly of claim **2**, wherein the microactuator comprises:

a bottom electrode;

a piezoelectric element on the bottom electrode; and

a top electrode on the piezoelectric element.

4. The slider assembly of claim **2**, wherein the microactuator comprises:

a bottom electrode;

a first piezoelectric element on the bottom electrode;

a shared electrode on the first piezoelectric element;

a second piezoelectric element on the shared electrode; and

a top electrode on the second piezoelectric element.

5. The slider assembly of claim **4**, wherein the microactuator further comprises:

a structural layer on one of the side surfaces of the slider body; and

an adhesive layer on the structural layer, the structural layer and the adhesive layer supporting the bottom electrode.

6. The slider assembly of claim 5, wherein the microactuator further comprises:

a buffer layer between the structural layer and the adhesive layer.

7. The slider assembly of claim 4, wherein the microactuator further comprises:

an encapsulation layer over the top electrode.

8. The slider assembly of claim 2, wherein each of the pair of structural elements is a microactuator responsive to electrical control signals to selectively complementarily bend to alter the position of the head portion with respect to the main portion of the slider body.

9. The slider assembly of claim 8, wherein each of the microactuators comprises:

a bottom electrode;

a piezoelectric element on the bottom electrode; and

a top electrode on the piezoelectric element.

10. The slider assembly of claim 8, wherein each of the microactuators comprises:

a bottom electrode;

a first piezoelectric element on the bottom electrode;

a shared electrode on the first piezoelectric element;

a second piezoelectric element on the shared electrode; and

a top electrode on the second piezoelectric element.

11. The slider assembly of claim 10, wherein each of the microactuators further comprises:

a structural layer on one of the side surfaces of the slider body; and

an adhesive layer on the structural layer, the structural layer and the adhesive layer supporting the bottom electrode.

12. The slider assembly of claim 11, wherein each of the microactuators further comprises:

a buffer layer between the structural layer and the adhesive layer.

13. The slider assembly of claim 10, wherein each of the microactuators further comprises:

an encapsulation layer over the top electrode.

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